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Agricultural Applications of DDT, with Special Reference to the Importance of Residues[1]

GEORGE C. DECKER[2]

In the short period that has elapsed since its insecticidal properties were first discovered, DDT has probably received more extensive research study than any other insecticide yet developed. We have learned much concerning proper methods for formulating DDT into an effective insecticide, and have developed a fair working knowledge of its potential usefulness, its limitations, and possible hazards. Despite all our research, however, entomologists find it difficult, if not indeed impossible, to make exact recommendations or even specific suggestions for the use of DDT to control insects, particularly those species which attack crops. This situaion arises, not because entomologists lack the ability and foresight required in the development of control measures involving the use of a potent insecticide like DDT, but rather because they have not had sufficient time to complete necessary field tests and because they have been constantly hampered by vague warnings and rumors concerning potential hazards to DDT users and consumers of treated products.

Because of its military importance, the control of insect pests attacking man or domestic animals and household pests has been the subject of intensive and extensive research. Within this field, therefore, the recommendations being made by representatives of federal, state and commercial institutions approach agreement.

In the agricultural field, thousands of pounds of DDT in the form of solutions, emulsions and suspensions will be used for the control of flies, fleas, lice, and other pests that attack livestock or invade farm buildings. If proper precautions are taken to avoid contaminating exposed food, feed, or utensils in which food may be handled when DDT preparations are applied for the control of such pests and recommendations by competent entomologists are followed, the residue problems should be negligible.

In approaching a consideration of the use of DDT on plants, particularly agricultural crops, we must first consider the limitations of our knowledge and admit that for the most part work in this field is still definitely in the experimental stage. Research on some of the problems in this field has advanced to the point at which entomologists may and, perhaps, should make suitable suggestions, if not indeed recommendations, for the guidance of growers who wish to use insecticides containing DDT for the control of certain insect pests on specific crops. Millions of pounds of DDT have been processed into dust concentrates and wettable powders, and undoubtedly large quantities of this material will find their way into the hands of American farmers and gardeners. Sizeable quantities of this material will inevitably be used on agricultural crops of one type or another. Some may argue that we are not our brother's keeper and that we will in no way be responsible for the misuse of these materials. At the same time, entomologists do have in their possession a working knowledge of how DDT may be used on several crops and also a fair knowledge of the hazards involved. In a sense they are therefore obligated to advise the farmer so that he may protect his crops and at the same time avoid misuse of the materials he obtains.

The decision to be made in some cases is of greater importance than some people realize. Wherever the residue hazard is known to be real and not a remote possibility there is no question what action

[1] An address delivered before the Insect Control Committee of the National Research Council on May 24, 1946.

[2] Entomologist, Illinois Natural History Survey and Illinois Agricultural Experiment Station, Urbana, Illinois.

should be taken. On the other hand, the United States has encountered difficulty in fulfilling its commitments for food to be shipped abroad. Our food reserves have been depleted and we are asked to tighten our belts. The supply of nearly every insecticide used in America is short. Rotenone and nicotine are practically unavailable and yet if our farmers are to produce maximum crops so that Americans will not be hungry and Europeans starve, insect pests must be controlled. In such an emergency the use of DDT on crops where the residue problem would be negligible or at least remote should not only be sanctioned but should be encouraged. Otherwise the remote possibility that some individual man or animal may suffer is balanced against the probability that many will suffer hunger or perhaps death due to starvation. To subscribe to the philosophy that DDT is too dangerous for use on agricultural crops would support the contention of some who feel its manufacture and sale as an agricultural insecticide should not have been permitted.

The potential agricultural uses for DDT are numerous and varied. In many instances DDT has proved to be more effective than other insecticides now available in controlling common insect pests of fruits and vegetables, and it may therefore replace or supplement some of the older insecticides now in common use. Because of its high toxicity, lasting residual effectiveness and low cost it may conceivably be extensively used for the control of insect pests heretofore not controlled through the use of insecticides.

In the production of many agricultural crops, the use of DDT involves few or no hazards. The Irish potato will serve as an excellent example. Research data from many laboratories show that DDT is outstandingly effective in controlling practically all of the serious insect pests of potatoes. Since the edible tubers are produced below ground and the treated portion of the plant is not used for any purpose, the residue problem does not exist, and there is no valid reason for not recommending the use of DDT on this crop. Sweet potatoes, peanuts and perhaps onions may also be considered to fall in this category. The residue hazard is likewise negligible in the case of all crops produced entirely for seed, provided, of course, no attempt was made to salvage crop residues for feed. Crops such as cotton and tobacco where no portion of the plant is used for food or fodder may, of course, be treated with DDT without much regard for possible residues. There seems to be little reason to discourage the use of DDT on shade trees and ornamental plants.

In the case of many crops the plants produce extensive vegetative growth which has to be protected from insect attack in advance of the appearance of the fruit or edible portions of the plant, and in such cases DDT may be advantageously used on these crops early in the season. Cabbage, cauliflower, lettuce, grapes, berries, beans, peas, and several other crops which frequently require one or more applications of an insecticide prior to the development of fruit, heads, or other edible portions fall within this category. The use of DDT on such crops during the early part of the season is unobjectionable.

In the case of most cereal crops, the grain or seed is covered by a glume, shuck, or other protective covering, and even when treated with an insecticide containing DDT, there is little likelihood that the seeds will ever be dangerously contaminated. However, in all cases where crop residues are to be salvaged for fodder, these crops have to be considered in the same light as forage crops. In the case of market garden sweet corn, canning corn and seed corn, where the ear is protected by a shuck, the use of DDT sprays and dusts appears sound, logical, and safe. In most cases the treatment applied for the control of the first brood of corn borers will be practically completed before the ears are produced and residues would be subjected to a considerable period of weathering before harvest time.

Generally speaking, the use of DDT on forage crops involves one of the greatest hazards, and until these residue hazards have been thoroughly studied and evaluated, the use of DDT on forage crops should not be encouraged. It is entirely possible, however, that some forage crops may be safely and economically protected from certain insect pests through the careful and judicious use of DDT. It appears possible that thousands of acres of sweet clover now annually destroyed

by the sweet clover weevil may be saved by light applications of a DDT dust applied shortly after the seedling plants appear above the surface of the ground. It also appears possible that serious leafhopper damage on second and third cuttings of alfalfa may be greatly reduced or eliminated by applying a very light application of DDT spray or dust as soon as the previous crop has been removed and before the plants make any appreciable new growth. In either case the residue problem is practically non-existent.

Because of the outstanding performance of DDT in controlling the codling moth, orchardists in many sections of the country are using considerable quantities of this new insecticide for the protection of their fruit crops. It appears that fruit growers will have little difficulty in developing spray schedules that will permit the use of DDT for the control of at least the first brood of codling moth and stay well within the present administrative tolerance.

In hastily reviewing the possible agricultural uses for DDT, residues were casually mentioned, but this all important problem must be given careful and thoughtful consideration and study. What are the hazards involved in the use of DDT? A layman or research worker can often find in the same article statements to the effect that DDT is not as toxic to warm blooded animals as lead, arsenic, fluorine, and other materials commonly used in insecticides and a statement that residues on food or fodder might be extremely dangerous to man or animals. This, of course, merely adds to his confusion. The establishment of an arbitrary tolerance of, let us say, 7 parts per million does not necessarily mean that larger amounts of the toxicant would be extremely dangerous nor insure that smaller amounts may not, at least under some conditions, prove to be harmful. Such a tolerance, whether legal or administrative, does however give the grower and research worker a landmark to go by. The orchardists have tolerances established for their guidance, but the producers of practically all other agricultural crops are left without guideposts. Not infrequently it is assumed that the tolerance of 7 p.p.m. applies to all marketable products. In many instances it will be argued that if 7 parts per million is safe on fruit it should be equally safe on vegetables and forage crops. The fact remains, however, that the majority of our farmers receive only vague cautions or threats and little or no actually tangible data or concrete advice. Perhaps even this condition is better than having arbitrary tolerances established at unjustifiably low levels. Such restrictions would impose useless obstacles in the path of progressive research and frequently deprive the farmer of the right to protect his crop in a safe, sane and economical manner.

The entomologist frequently finds himself in difficult positions. He is expected to assist the farmers by supplying information on the latest and best possible recommendations for the control of insect pests. At the same time, he is obligated to guard against recommending any procedure or treatment that might endanger the life or health of man or beast. In the absence of reliable data, he must proceed with reasonable caution and must at all times avoid being carried away by current waves of public opinion. Today, he must balance the merits of DDT against the hazards that might accompany its use and weigh carefully the evidence on both sides of the equation.

DDT has been used extensively by the armed forces, research workers, and laymen, sometimes carelessly and promiscuously; yet Dr. Neal recently reported that no instance has been found in which a person has been poisoned from the use of DDT itself in insect control operations. Perhaps the same statement could be made for domestic animals. It would appear toxicologists agree that the acute and subacute toxicity of DDT to warm blooded animals is no greater and some say much lower than that of several materials now in common use as insecticides. The U. S. Food and Drug Administration has for all practical purposes acknowledged this fact in establishing its tentative administrative tolerance of 7 parts per million (about 0.05 grains per pound) for DDT on apples and pears.

DDT has undoubtedly been subjected to more critical toxicological study than has any other insecticide. There is an abundance of research data to show that DDT is poisonous to warm blooded animals when ingested, injected, or absorbed

into the body in considerable quantities, but very little information is available, or at least published, regarding the effect on animals of small quantities of DDT such as may be encountered in crop residues. No doubt there are experiments in progress and perhaps some data available that will shed light on this subject. For the most part published reports involve animals fed large amounts of DDT (50 to 200+ mg. of DDT per kilogram of body weight) to determine the acute or subacute range of toxicity.

In many cases studies to determine the cumulative effect of DDT have involved the use of foods containing 500 to 1,000 or more parts of DDT per million. Even at these high dosages, rats, pigs, and goats have been able to survive long feeding periods. In our own laboratories, swine fed corn containing 555 parts of DDT per million (0.5 ounce of DDT per bushel of corn) from the day they were weaned, January 2, until they were butchered 7 months later (August 8) remained normal and healthy. Post mortem studies and histological examinations of sections of kidney and liver tissues showed no disorders whatever. Chemical analyses of leaf fat from these animals made by chemists of the U. S. Food and Drug Administration laboratories showed DDT stored in the fat in amounts ranging from 271 to 387 parts per million. DDT in liver tissue ranged from 1.6 to 3.6 p.p.m. and DDT in kidney tissue ranged from 1.2 to 32.0 p.p.m. The accumulation of over 300 p.p.m. of DDT in the fat of these animals is disturbing, to say the least. At the same time, we must bear in mind the daily food of these animals for 7 months contained well over 500 p.p.m. of DDT, which is roughly 80 times the tolerance permitted on apples and pears.

Unfortunately, very little data are available to indicate the range of DDT residues that might be expected on treated crops. Preliminary results of residue studies on apples are available from several states and these data may give us a picture of what to expect. In the first place, DDT on plants does not remain effective for long periods of time. Dosages up to 1 pound of DDT per 100 gallons are ineffective after 2 to 4 weeks, indicating that DDT is lost or decomposed. There are several reports indicating residues below 7 parts per million on apples sprayed 4 to 7 times with DDT at rates of 8 ounces to 1 pound per 100 gallons. A casual review of the available data would indicate that the elapsed time between the last spray application and harvest has a much greater influence on the DDT deposit than the number of sprays or amounts of DDT used. In heavy DDT schedules the addition of a summer oil or sticker will almost certainly produce residues in excess of the tolerance. However, if stickers are omitted and the trees are not sprayed within 4 to 6 weeks of harvest, several sprays containing 1 pound of DDT per 100 gallons may be applied without producing a residue in excess of the tolerance. It should be noted that orchardists commonly use 400 to 600 gallons of spray (4 to 6 pounds of DDT) per application per acre.

Dr. Thomas C. Watkins, of the New York Station, graciously provided the writer with unpublished data on DDT residues on head lettuce and onions. Dr. Watkins found that the trimmings from lettuce heads and onion bulbs heavily dusted two or three times with a dust containing 3 per cent DDT showed residues in excess of 7 parts per million but the edible portion of the onions and lettuce heads usually showed DDT to be less than 1 part per million. In his work Dr. Watkins began dusting five lettuce plots August 14. Each week one plot was dropped and the rest dusted again with a dust containing 3 per cent DDT. He therefore had plots dusted 1, 2, 3, 4, and 5 times respectively. All plots were harvested September 14, 2 days after Plot 5 was dusted the fifth time. The DDT residues on trimmed lettuce heads (in parts per million) obtained were: 0.2, 0.2, 4, 20, and 211 respectively. Residues on the trimmings were reported as: 4, 12, 110, 185, and 358 parts per million. Here again it is evident the elapsed time between the last treatment and harvest is far more important than the number of applications or total dosages. If the total amount of DDT applied determined the residue, the data should more nearly approach an artihmetic progression, e.g.: 0.2, 0.4, 0.6, 0.8, and 1.0 p.p.m.; and 4, 8, 12, 16 and 20 p.p.m.

The corn borer "Pool of Information" contains data provided by the Bureau of Entomology and Plant Quarantine giving

DDT residues on corn treated for European corn borer control. Residue analyses on corn sprayed four times using 0.85 to 0.95 pounds of DDT per acre showed: Stalks, 0.32 p.p.m.; husks and silks, 0.006; and corn kernels 0.008. Analyses of corn treated four times with a dust containing 2.5 per cent DDT showed: Stalks and leaves, 1.88 p.p.m.; husks and silks, none; and kernels, 1.59. Corn treated four times with a 5 per cent DDT dust showed: Stalks and leaves, 2.1 p.p.m.; husks and silks, 0.04 p.p.m.; and kernels 0.13. In our experiments an analysis of silage made from corn 10 days after the last of three applications of 5 per cent DDT dust applied at the rate of 20 pounds per acre showed the DDT present amounted to 4 p.p.m.

All of the data available to the writer show that if a reasonable time elapses between treatment and harvest, DDT may be used on a number of crops without fear of building large DDT residues. However, the question of how extensively DDT may be used on fruits, vegetables, and other agricultural crops without endangering the health of man or animals remains unanswered. In the light of the residues just reviewed it would appear that reasonable caution in the use of DDT on fruits and vegetables is all that safety requires. We have all been very cautious about recommending the use of DDT on fruits or vegetables but at the same time we must admit that there is little or no evidence to show that residues from the small amount of DDT required to control insect pests would in any way endanger human life or health.

In the case of animals there is considerable biological data, all of which tends to show that cattle, swine, sheep, goats, chickens and laboratory animals can, over long periods of time, ingest daily amounts of DDT far in excess of what might be expected as a residue on plants without showing any ill effects. The writer has no knowledge of even a single authentic recorded case of animal poisoning as a result of their feeding on DDT-treated plants. Sheep and dairy cows fed DDT-treated silage for a period of several months reportedly maintained normal appetites and apparent good health.

At our laboratories feeder steers receiving daily for three months 40 pounds of silage made from corn dusted three times with a 5 per cent DDT dust applied at the rate of 20 pounds per acre maintained normal health, and post mortem studies showed no signs of tissue damage. In repeated tests swine fed corn containing DDT far in excess of any possible residues for a period of several months have never shown any symptoms of DDT poisoning, and post mortem examinations have not disclosed damage to muscle, nerve, kidney or liver tissues. Chickens, both hens and baby chicks, whose sole diet consisted of a mash containing 111 p.p.m. of DDT were apparently well and healthy at the end of a 10-week feeding period.

In translating the results of laboratory tests to practical field conditions, we must bear in mind no animal's diet is restricted to a single item, that seldom if ever will all of any one component of the diet bear DDT residues, and above all we must remember that every feeding test yet reported has involved amounts of DDT in excess of probable residues.

The fact that animals can and do store DDT in fat and also eliminate DDT in the butterfat contained in their milk has given rise to new fears that the use of DDT may prove disastrous. The preliminary work in this field, as in many others, involved animals fed DDT in amounts approaching the sub-acute toxic level. The discovery and recording of this scientific fact is commendable, but until there is concrete evidence that animals receiving only normal residues in a representative part of their diet also eliminate dangerous amounts of DDT in their milk, this type of information should not be given wide publicity. Our obligation to avoid starting or fostering unwarranted fears is just as great as our obligation to warn the public of known hazards. No one will question the wisdom of cautioning against the feeding of DDT to dairy animals until this problem is solved. However, the fact that a few laboratory animals eventually died from drinking milk obtained from animals receiving 1 part of DDT per 1000 parts of food in their diet hardly justifies the fear that a few cows eating corn, pea vines, or cabbage leaves treated with DDT would endanger the milk supply of Chicago, Detroit or New York.

At the present time, May, 1946, one of the greatest hazards involved in the use of

DDT is psychological in nature. As a result of the extensive unfavorable publicity given to DDT in the last year, many users are extremely apprehensive, and they frequently attribute a sore throat, headache, indigestion, lumbago, and imaginary ills to their contact with DDT. In the same vein, it is doubtful that any animals will become ill or die of natural causes on properties treated with DDT.

Most entomologists fear that the extensive use of DDT will inevitably be accompanied by a few accidents and instances of careless misuse of the material. Such instances will, of course, be regrettable but do not constitute grounds for condemning the use of DDT. Such accidents have occurred with the use of lead arsenate, calcium arsenate, fluorine compounds, dimitro ortho cresol, kerosene, creosote, and other materials used in insect control work. The fact that no such accidents have occurred with DDT is not particularly surprising but is very encouraging.

In many instances only the uncertainties surrounding the residue problem preclude the use of DDT on agricultural crops. This problem is therefore of prime importance and demands our best research efforts. The entomologists and chemists should as quickly as possible determine: The deposits of DDT found on plants immediately after treatment at known rates of application, the rate of decomposition or loss of DDT from the plants, the residues obtained at harvest time, following various practical spraying or dusting schedules, and the possible value of neutralizing or decontaminating sprays if such are needed. The toxicologists and chemists should determine the effect of DDT at residue levels on animals and animal products.

The attainment of our goal can best be obtained through the whole-hearted cooperation of all interested agencies and the elimination of all unnecessary duplication. A shortage of adequate facilities and trained chemists capable of making accurate and reliable DDT determinations seems to be limiting our forward progress at this time. Few Experiment Stations are able to provide adequate facilities for such work, and federal agencies, though willing, are unable to help state institutions because they are understaffed and overworked. Many workers have found to their sorrow that having no chemical analyses at all is better than unreliable data, and they are reluctant to submit materials to chemical laboratories whose chemists are not trained for this special type of work. Samples for residue analysis are available as a by-product of every entomologist's field plot, and animal tissues are at least potentially available from every animal used in feeding experiments. Therefore, since residue analyses and DDT determinations on animal tissues are so badly needed, it is exceedingly regrettable that adequate facilities for making chemical analyses are not available.

At a recent meeting in St. Louis, Missouri, the writer expressed a hope that manufacturers of DDT or others interested in the problem might pool resources and develop a fund which would enable the Bureau of Entomology and Plant Quarantine, the Food and Drug Administration or Public Health Service individually or collectively to establish a laboratory or laboratories where research workers might submit samples and obtain reliable analyses. In closing, I repeat that hope and add to it the sincere hope that this year we may obtain a fairly complete picture of the residues that may be expected on crops and determine the effect of such residues on animals.—5-30-46.

CUMBERLAND-SHENANDOAH FRUIT WORKERS' CONFERENCE

The Cumberland-Shenandoah Fruit Workers, Conference, an important feature of which is the annual Spray Conference for the states of Pennsylvania, Maryland, Virginia, West Virginia and Delaware, is scheduled to meet in Frederick, Maryland, on November 29 and 30, 1946, with headquarters at the Francis Scott Key Hotel. A report of the Conference will appear in a later issue of the JOURNAL.

A Review of North American Economic Eriophyid Mites[1]

H. H. KEIFER,[2] *California State Department of Agriculture, Sacramento*

The Eriophyid mites, variously known as gall mites, blister mites, rust mites, and bud mites, are the smallest animals bearing an exterior skeleton with which the agriculturist has to contend. They deform and russet leaves and fruit, blast buds, and if uncontrolled will frequently put their host plant out of production.

These mites are very tiny, averaging about 200 to the inch. They cannot be seen, or barely so, by the unaided eye, and for that reason their structure and habits have been obscure. We need much more accurate information on the correct identity and bionomics of species on economic hosts. This review, for that reason, is partly a discussion of what we do not know about these mites, as well as a summary of the more important economic species of the continent. While this account is necessarily from a California viewpoint, it is also true that California agriculture has as many, or more problems, due to Eriophyid activity, as any other North American area.

The bionomics of Eriophyid mites as far as we know is based on the existence of perennial hosts, upon the need of the mites to feed and breed in connection with soft, usually green tissue, and upon the necessity for the development of large populations to insure distribution of the mites to additional individuals of their host plants. The small size of Eriophyids in relation to food quantity makes the development of large populations possible. The ability of the individual mites to hatch, pass through two nymphal stages, and become egg-laying adults in a little over a week, under favorable conditions, is the solution to the other part of this population development problem.

Eriophyids lack control over their means of distribution and must travel by chance, their numbers gaining the aid of the law of probability. They depend on wind, insects, birds, and other carriers Most species are very widely distributed, which fact is the measure of their success in traveling to the correct places, and in staying on plants which are being moved.

Eriophyids exhibit a very intimate mite-host relationship, characterized by considerable host specificity. Gall formation is another aspect of this intimacy, but the majority depend on natural formations on their hosts and cause no discernible injury. They remain in locations where feeding and breeding can take place whenever temperature permits, with few exceptions. The exceptions are specialized aestivating and forms which spend their quiescent period in dry bark crevices.

In general there are two types of Eriophyids: the worm-like soft kinds that are gall mites or bud mites, and which do all their feeding and breeding under cover, and the rust mites, which are broader and chunkier, often rather flat, which have heavy back plates to protect them against the action of light and desiccation, and which feed and breed more or less on open-leaf surfaces. This latter type, with few exceptions, constitutes the rust mites, or leaf vagrants.

A few comments are necessary on the hibernating forms of the rust mites on deciduous trees, which forms are known as *deutogynes*. These hibernating mites develop on the open-leaf surfaces, usually in response to the maturing of the leaves, or to the oncoming leaf-drop in the fall of the year. As far as we know at present, none of these hibernating forms can reproduce in the season in which they are formed; but in the case of pear, the rust mite deutogynes *may* have the ability to come out of aestivation before cold weather, when there is a second flush of new growth which provides fresh leaves.

On pear trees, during the winter, deutogynes of the pear rust mite are found in the bark crevices at the apex of the second-year wood. The pear leaf blister mite on the other hand, which is one of the worm-like types, is found exclusively in the buds, usually terminal buds. This

[1] Presented on the program of the Pacific Slope Branch, June 26, 1946.

[2] The writer acknowledges with thanks the assistance given by Dr. L. M. Smith and Dr. E. M. Stafford, University of California at Davis; Dr. A. M. Boyce, University of California at Riverside; and by John B. Steinweden, State Department of Agriculture.

example illustrates one of the fundamental differences between these two types of mites.

ACARICIDES.—Eriophyids have no organization similar to the tracheal system of higher Arthropods. For that reason the skin is presumably the oxygen-absorbing organ, putting this function in a very vulnerable position. This may in part account for the effectiveness of sulfur, or certain sulfur derivatives, against these mites, since sulfur is an element closely related to oxygen. Thus we may conjecture that the sulfur, or sulfur compound, is absorbed in somewhat the same manner as oxygen, or with it, but from then on blocks their breathing apparatus.

Sulfur as a pure chemical has a slight vapor pressure at ordinary temperatures and will slowly sublime, the rate depending on the temperature. This vapor is presumably the form of the element deadly to Eriophyids, since mites will die, confined in a chamber coated with sulfur, though no solid sulfur has touched them.[1] This is the indication that in mite control the atmospheric temperature is a factor. The percentage of sulfur in a combination dust can be quite low under favorable conditions, providing an even coverage is achieved. But pure sulfur is so cheap that diluents usually add to cost, unless there is some other important objective.

Sulfur for Eriophyid mite control is put on in a number of ways. Pure sulfur dust, or with a small amount of sticker such as rosin, readily suppresses the tomato russet mite. Wettable sulfur is another form of mite treatment, the pulverized sulfur bearing a wetting agent such as glue, dextrin, calcium caseinate, flour, or specialized detergents.

Lime-sulfur is a common form of the element used as a spray. This is variously described as a water solution of calcium polysulfide, or sulfur dissolved in calcium sulfide. The mixture contains some free calcium hydroxide and free hydrogen sulfide, but the important fact is that it deposits free sulfur. When combined with oil emulsion, lime-sulfur has better penetrating power, and is more suitable for reaching mites which have sequestered themselves far down behind bud scales.

Lime-sulfur is usually a fall, winter, and early spring application, when it is used in strengths varying from 1 to 10 to 1 to 20 in water. The leaf sprays are diluted down to 1 or 2 per cent to reduce burning as much as possible.

When lime-sulfur is inadvisable because of possible plant injury, there are other alternatives besides sulfur dust or wettable sulfur. Petroleum oil spray suitable for covering tender foliage is a satisfactory suppression method in the case of the citrus budmite. On the cereal rust mite a dust of sulfur and calcium cyanamide seems effective. For the blueberry bud mite, sprays and dusts containing derivatives of dinitro-ortho-cyclohexylphenol show promise. Certain selenium compounds may also suppress Eriophyids.

The tenacity with which many of these mites remain on their host trees or shrubs after applications of acaricides indicates in part the difficulty the control man faces in devising a material which will penetrate far enough into crevices. However, if the tree is effectively rid of mites during the winter, it can start the coming season comparatively free from damage, since the law of probability operates with some deliberation in redistributing Eriophyids.

PREDATORS.—The most common predators of Eriophyids are parasitic mites of the *Seius pomi* type. They occur everywhere and their actual importance needs further investigation since they may prevent severe mite damage at times. They are most effective on open-leaf mites, but enter galls when the aperture is large enough (they are quite a bit larger than Eriophyids), and are very common on erineum patches. Other types of predacious mites occur in company with the citrus bud mite, one of which is a Cheyletid.

Predacious thrips[2] and Cecidomyid maggots feed on Eriophyids in California. In England Chalcid[3] wasp larvae are on record as preying on the black currant gall mite in the big buds. The writer has noted Chalcid larvae in West Indian mite galls. A Tortricid caterpillar, lacewing larvae, Syrphid maggots, and others[3] also find mention in this connection. When atmospheric humidity is suitable, fungi may be a factor in gall mite survival.

[1] Shepard—The Chemistry and Toxicology of Insecticides, Burgess Publishing Co., p. 137, 1939.

[2] Bailey—Jour. Econ. Ent. V. 33, No. 3, p. 540, 1940.

[3] Massee—Bul. Ent. Res. V. 18, part 3, p. 302, 1928.

ECONOMIC SPECIES.—The mite species which are of more or less economic importance in North America number about 50.[1] Of these the pear leaf blister mite is perhaps the most generally known, and one of the most important, since it can put its host out of fruit production. It costs in the neighborhood of $10.00 to $12.00 per acre to spray for this mite, and so far, no completely satisfactory control method is available. The typical blister-mite, *Eriophyes pyri* (Pgst.), winters in the terminal buds, forms blisters in the very tiny spring leaves, and on the very small fruit. These blisters on the leaves persist as black spots throughout the season, or as long as the leaf remains on the tree. On the fruit, the blister is obliterated except for a characteristic slight depression and scar. The usual type of control for the pear leaf blister mite is lime sulfur in late fall and early spring.

A biological form of this mite, concerning which we know too little at present is sometimes called the *pear bud mite*. In cases where pear trees show no leaf blisters, the early spring bud blasting may be nevertheless so severe, due to bud mite, as seriously to curtail the pear crop. In fact, leaf blisters, as such, are not a particular menace to pear growth unless there is a tremendous amount of them, whereas this bud blasting is definitely a very serious factor in fruit production since it destroys the young blossoms. It will be necessary to culture these bud and blister mites on pear to discover what the relationship between the two types is.

Some suggest that control measures have selected out a non-blistering strain of *Eriophyes pyri*, since those out on the leaves are more vulnerable than those which would tend to remain in the buds under the tightly-fitting scales.

The only other Eriophyid which attacks pear, so far as available specimens indicate,[2] is the pear rust mite, *Epitrimerus pyri* (Nal.). The damage caused by this mite characteristically happens in spring and early summer since the species seems sensitive to mature leaves and produces deutogynes that proceed to aestivate. The fact that the rust mite will reappear on summer flushes of new growth may mean the deutogynes can reproduce the same year they develop. It will be necessary to culture this mite to discover just what takes place. Oil sprays or sulfur dusts suitable for tender leaves are presumably good acaricides for this mite, but winter lime-sulfur will prevent spring injury.

A mite close to *Eriophyes pyri* is the apple blister mite. The relationship between this mite and the pear leaf blister mite needs to be settled by cultural methods. For the moment, the technical name of this mite had probably best be stated as *Eriophyes pyri mali* Nal. There is another mite on apple which, while closely related to the blister mite, nevertheless seems distinct. It could be called the apple bud mite, and while little attention has been paid to it, the destruction of apple flowers in the spring may take place in considerable quantity. Apple trees, with numerous mites in the buds and around the petiole bases, which have spring blossom damage, nevertheless can be without leaf blisters.

The rust mite situation on apple is somewhat different from that on pear. The usually designated apple rust mite, *Vasates schlechtendali* (Nal.) seems to be generally distributed throughout North America. Its method of over-wintering and the possible production of deutogynes by this species remain obscure.

A second rust mite on apple, *Calepitrimerus baileyi* K., is the one most common in California. This latter mite works on apple leaves throughout the season and causes a distinct rusting of the undersurfaces. The mite takes advantage of and thrives best under the protection afforded by apple leaves which have a relatively dense underside growth of hair. The deutogynes of *C. baileyi* winter on the fruit spurs around the lateral buds.

None of these mites on apple has received a great deal of economic attention and information on control measures is not available.

The Eriophyid mites on grape lack greater importance than they have largely because grapes are so consistently sulfured for mildew. Nevertheless, there are two kinds of these mites known in North America, namely, the grape erineum mite,

[1] The 1939 edition of Destructive and Useful Insects by Metcalf and Flint lists four economic Eriophyids. This book is primarily written from an eastern viewpoint. In contrast, California agriculture suffers from the attacks of between 10 and 15 species of these mites.

[2] Pear trees at Davis, California, had only *Epitrimerus pyri* on the leaves. Apple trees nearby had both *Calepitrimerus baileyi* and *Vasates schlechtendali*, the latter said to attack pear also. See the discussion about apple.

Eriophyes vitis (Pgst.), and the grape rust mite, *Calepitrimerus vitis* (Can.). The former species forms erineum patches on the under surface of the leaves and there seems to be a certain amount of varietal resistance to the activities of this mite shown by different kinds of grapes. For example, one kind of grape which is fairly well over-run with erineum patches has been observed to be interlocked with another variety of grape which had few or no erineum patches. In this case, no control measures had been attempted.

Some critical cultural work on the grape erineum mite, by Dr. L. M. Smith of Davis, illustrates a principle in connection with gall mite activity, namely, that the gall can only be formed on very tiny leaves and that after the leaf has reached a certain stage of development, no further extension of galls can take place. Here again on grape, we find what appears to be a bud mite development, since Dr. Smith has shown that bud damage by mites can occur on grape vines without the production of any erineum.

The grape rust mite, which develops deutogynes in the fall, has received little attention in North America. European references to the work of this mite would seem to indicate that they have the deutogynes catalogued as a different species. That situation very much needs clarification.

Both *Eriophyes vitis* and the deutogynes of *Calepitrimerus vitis* are easily recoverable in winter grape buds.

On citrus, the rust mite, *Phyllocoptruta oleivorus* (Ashm.) is a pest of long standing in the warmest citrus-growing areas of the United States. All forms of citrus may suffer from an attack of this mite, although it seems to have local host strains and to prefer lemon in California, for example. Work with the control of this mite in Florida indicates sulfur is the best agent and that nicotine sprays and oil sprays were not very effective. This mite, which is on an evergreen host, winters on the leaves and produces no specialized hibernating forms.

In California, the most important citrus Eriophyid pest is the citrus bud mite, *Aceria sheldoni* (Ewing). It was first discovered in 1937 and has since that time been gradually extending its activities, occupying practically all of the citrus-growing areas adjacent to the coast in Southern California. Severely damaged lemon trees show stunting and clustering of the young growth, and severe leaf and fruit malformation. These mites leave a characteristic brown condition in the buds in which they work. They may be found developing in large numbers under fruit buttons where they also leave a brown injury. While sulfur applications are effective against this mite, host damage indicates that petroleum oil spray is the best all-round control.

The cost of the spray for this mite on lemons, according to Dr. A. M. Boyce, who has worked with the species since its discovery, is in the neighborhood of $50.00 an acre for the season.

The citrus bud mite also works on oranges and grapefruit and seems to have a general range through the Pacific citrus-growing areas. Very similar or identical populations damage citrus in such places as Hawaii, Australia and Java.

Peach is infested by one Eriophyid, namely, the silver mite, *Vasates cornutus* (Banks). This mite winters around the lateral buds from 3 to 12 inches below the terminals, in the form of deutogynes. In the early spring, these mites invade the tender growing tips, and at that time, if the host plant lacks leaf glands, or if the leaf glands are not operating properly (these produce a sticky secretion), the mites cause an unhealthy longitudinal rolling of the leaves and, in some cases, numerous fine yellow dots on the leaves. This injury is not to be confused with the silvering of the peach leaf, which silvering occurs after prolonged feeding during spring and summer. The mite feeds on both leaf surfaces and produces deutogynes only in response to the temperature drop in the fall.

The plum nursery mite, *Vasates fockeui* (Nal. & Trt.), is found throughout the northern states and Canada. It severely damages young growth on plums which accounts for its common name. This mite is closely similar to the peach silver mite, no characters at the present time being available to indicate a structural distinction between the two. Such a mite is either uncommon or absent from the fruit-growing areas in California, where peach silver mites abound, since plum trees in the vicinity of infested peach trees do not

develop mites of the *V. fockeui* type. The explanation of this awaits further study and culture.

Filbert and currant suffer from the attacks of big-bud mites, *Phytoptus avellanae* Nal., and *Cecidophyes ribis* Nal., respectively. The terminal buds on certain filbert varieties enlarge in the spring, and turn into galls never producing shoots. The filbert mite is unique in having two types of nymphs, a normal type developing in the big-buds, and a flattened nymph which spends the summer on the undersides of the leaves.

The redberry mite on blackberries along the Pacific Coast, namely, *Aceria essigi* Hassan, insures itself a breeding place in an unusual manner. Feeding in the developing berry by this mite causes either all of the drupelets, or the basal ones, to remain red and unripe. The berry thus hangs on the vine longer, and is unfit for eating.

The Eriophyid with the most peculiar habitat, that has come to notice so far, is the onion or bulb Eriophyid, *Aceria tulipae* (K.). Liliaceous bulbs such as onion, garlic and tulip are attacked, the mites living between the bulb layers. Thus the mite lives underground, a habit not known to be possessed by any other species. The activities of *Aceria tulipae* cause the bulbs to shrink and dry out. These mites persist in storage.

SUMMARY.—Eriophyid mites are minute animals concerning which we need more information, particularly that to be secured by means of cultural studies. They have an intimate attachment to their hosts, which hosts must be fundamentally perennial. The mites have no control over their means of distribution, so must develop large enough populations to insure that some individuals will arrive at the correct destinations.

There are two general types of Eriophyids: 1, The worm-like gall mites and the bud mites; 2. The harder bodied, open-leaf mites which are usually more flattened and chunky. The species of this second type which are attached to deciduous trees usually develop deutogynes which are hibernating females which probably cannot reproduce during the season they are formed.

There seems to be a tendency for certain economic gall mites to divest themselves of the gall-making habit and to remain bud mites. They do more damage to their host in this latter capacity and are more protected against acaricides. This whole question needs study.

Since Eriophyids breathe through the skin, we may hypothesize that part of the reason sulfur is effective against them is because it blocks oxygen intake. Lime-sulfur is a usual acaricide used for suppressing Eriophyids, but sulfur dust, wettable sulfur, petroleum oil, calcium cyanamide, and dinitro dusts are also available.

Eriophyid mites are subject to natural control by predacious mites, thrips, maggots, and possibly fungi. The status of these controlling factors remains for investigation.

The following list of economic Eriophyids seeks to set forth concisely the more important species, indexed by host:

Aloe
  Aloe wart mite, *Aceria*[1] *aloinis* (K.).
    Distribution—Southern California.
    Injury to host—forms large warty deformations on inside of leaf bases, and in flowers; also on related plants.
    Ref.: Keifer—Bul. Cal. Dept. Agr. V. 30, No. 2, p. 205, 1941.

Apple
  Apple leaf blister mite, *Eriophyes pyri mali* Nal.
    Distribution—General.
    Injury—causes leaf blisters.
    Ref.: Nalepa—Marcellia V. 22, p. 63, 1925.
  Apple bud mite, *Eriophyes* sp.
    Distribution—General.
    Injury—Bud damage; kills flowers.
  Apple rust mite, *Vasates schlechtendali* (Nal.)[2]
    Distribution—General.
    Injury—Rusts leaves (also said to be on pear).
    Ref.: Insects Wn. N. Am. p. 50, 1926.
  Bailey's rust mite, *Calepitrimerus baileyi* K.
    Distribution—California, Utah; elsewhere?
    Injury—Rusts apple leaves.
    Ref.: Bul. Cal. Dept. Agr. V. 27, No. 3, p. 310, Sept. 7, 1938.
  Parrott's apple leaf vagrant, *Eriophyes malifoliae* Parrott.
    Distribution—New York State.
    Injury—None noted.
    Ref.: N. Y. Agr. Expt. Sta. Bul. 283, p. 312, 1906.
      (The figure suggests it is not *Eriophyes*, but a deutogyne of some rust mite.)

Berries, particularly blackberry (*Rubus* spp.)
  Red berry mite, *Aceria essigi* (Hassan).
    Distribution—Widespread along Pacific Coast.

[1] *Aceria* is a segregate of the older conception of *Eriophyes;* see Bul. Cal. Dept. Agr. Vol. 33, No. 1, p. 22, Apr. 13, 1944.

[2] *Vasates* is a segregate of the older conception of *Phyllocoptes;* see Bul. Cal. Dept. Agr. V. 33, No. 1, p. 25, Apr. 13, 1944. In V. 35, No. 1, p. 41, Apr. 16, 1946, is the description of *Vasates malivagrans* K. This mite does not fit the description of *schlechtendali* in some respects but the name *malivagrans* is being suppressed until more information is available.

Injury—Causes fruit to remain red, especially the basal drupelets.
Control—Lime sulfur and winter oil emulsion.
Ref.: Essig & Hoskin—Cal. Ext. Ser. Cir. 87, p. 34, 1944.

Blackberry leaf mite, *Phyllocoptes gracilis* (Nal.)[1]
Distribution—General.
Injury—Causes leaf spotting and deformation; premature fruit ripening and dry berry disease.
Ref.: Breakly 1945, Jour. Econ. Ent. 38, (1): 121; (6): 722.

Big-beaked plum mite, *Diptilomiopus gigantorhynchus* (Nal.)[2]
Distribution—Common on blackberry in parts of California; see plum.

Blueberry, Huckleberry (Vaccinium spp.)

Blueberry bud mite, *Aceria vaccinii* (K.)
Distribution—Eastern North America.
Injury—Deforms spring flower heads and fruit.
Control—Dinitro sprays said to be effective.
Ref.: Bul. Cal. Dept. Agr. V. 30, No. 2, p. 196, May 26, 1941.
Bailey & Bourne, 1946, JOUR. ECON ENT., 39 (1): 89.

Camellia

Camellia bud mite, *Aceria camelliae* K.
Distribution—California.
Injury—In flower buds, may cause premature flower drop.
Ref.: Bul. Cal. Dept. Agr. V. 34, No. 3, p. 137, 1945.

Purple or ribbed camellia mite, *Calacarus adornatus* (K.).[3]
Distribution—California, Southern States; Asia?
Injury—Rusts the leaves and deposits debris.
Ref.: 1940. Cal. Dept. Agr. 29 (3): 164.

Steinweden's camellia mite, *Acaphylla steinwedeni* K.
Distribution—California, Southern States; Asia.
Injury—Rusts leaves.
Ref.: 1943. Cal. Dept. Agr. 32 (3): 215.

Carrot

Carrot bud mite, *Aceria peucedani* (Can.).
Distribution—California; Europe.
Injury—Causes drying of seed heads.
Ref.: Nalepa 1929 Marcellia, 25: 135.

Celery

Celery rust mite, *Vasates eurynotus* (Nal.).
Distribution—California; Europe.
Injury—Rusts leaves and stems; also on carrots and other Umbellifers.
Ref.: Bul. Cal. Dept. Agr. 30 (2): 206. May 26, 1941.

Citrus

Citrus bud mite, *Aceria sheldoni* (Ewing).
Distribution—Southern California coast, Hawaii, Queensland, East Indies.
Injury—Deforms leaves and fruit, stunts growth, blackens buds (in California the mite prefers lemon).
Control—Petroleum oil sprays at least twice a year.
Ref.: Boyce & Korsmeier 1941, JOUR. ECON. ENT., 34 (6): 745.

Citrus rust mite, *Phyllocoptruta oleivorus* (Ashm.).
Distribution—Southern California, Southern Texas, Florida, elsewhere in citrus growing areas of the world.
Injury—Severely silvers the leaves and fruit (in California it prefers lemon in the San Diego vicinity).
Control—Sulfur dusts or sprays.
Ref.: Essig & Hoskins, 1944, Cal. Agr. Expt. Ser. Circ. 87: 50.

Cotton

Cotton blister mite, *Cecidophyes*[4] *gossypii* (Banks).
Distribution—Southern Florida; West Indies.
Injury—Causes hairy deformations of shoots and leaves, especially on young plants; destruction of fruiting forms.
Control—Destroy wild cotton which serves as the perennial host.
Ref.: Fife, 1937, Jour. Agr., Univ. of P. R., 21 (2): 169.

Currant

Currant big-bud mite, *Cecidophyes ribis* (Nal.).
Distribution—British Columbia; elsewhere in North America?, Europe.
Injury—Causes enlarged terminal bud-galls to appear in the summer; deforms plant; bears a relation to reversion disease.
Control—Spring application of lime-sulfur when flower racemes appear.
Ref.: Massee, 1927, Bul. Ent. Res., 18: 179. Massee, 1928 Bul. Ent. Res., 18: 297.

Fig

Fig bud mite, *Aceria ficus* (Cotte).
Distribution—California, Southern Europe.
Injury—Damages buds of young trees; in fruit.
Ref.: Baker, 1939, Bul. Cal. Dept. Agr., 28 (4): 266.

Big-beaked fig leaf mite, *Rhyncaphytoptus ficifoliae* K.
Distribution—California; Southern Europe?
Injury—None observed, but may be common on undersides of leaves.
Ref.: Baker, 1939, Bul. Cal. Dept. Agr., 28 (4): 273.

Filbert

Gilbert big-bug mite, *Phytoptus avellanae* Nal.
Distribution—Europe, North America.
Injury—Produces terminal bud gall; prefers certain varieties of cultivated filberts; not seen on wild filberts in California, but infests the wild plants in the East.
Ref.: Massee, 1930. Bull. Ent. Res., 21: 165; Keifer, 1940, Bul. Cal. Dept. Agr., 29 (2): 112.

Filbert bud mite, *Cecidophyes vermiformis* (Nal.).
Distribution—Europe, North America.
Injury—An inquilin in the big buds.
Ref.: 1944, Bul. Cal. Dept. Agr., 38 (1): 24.

Filbert leaf mite, *Coptophylla lamimani* (K.).
Distribution—California.
Injury—Common on filbert leaves.
Ref.: 1939, Bul. Cal. Dept. Agr., 28 (6): 419; 1944, Bul. Cal. Dept. Agr., 33 (1): 26.

[1] Formerly *Eriophyes gracilis* Nal.
[2] *Diptilomiopus prunorum* K., Bul. Cal. Dept. Agr. V. 28, No. 2, p. 140, Mar. 17, 1939, is being suppressed in favor of the name *D. gigantorhynchus* (Nal.) until more data is available.
[3] Perhaps the same as "*Eriophyes carinatus*" Green of Asia, known as the ribbed tea mite. This name was not accompanied by a description. See King—Jour. Ent. Res. 28, (2): 311, 1937. Regardless of the specific name, this tea mite is in no sense an *Eriophyes*.
[4] *Cecidophyes* in a segregate of the older conception of Eriophyes; see Bul. Cal. Dept. Agr. V. 33, No. 1, p. 24, Apr. 13, 1944.

Grape
Grape erineum mite, *Eriophyes vitis* (Pgst.)
Distribution—Wherever grapes are grown.
Injury—Forms undersurface erineum patches on the leaves, occasionally overrunning and deforming the whole leaf; the bud form blasts buds.
Control—Sulfur dusts for mildew, and pruning practices reduce this mite to a negligible status in most cases; the bud form may be harder to control.
Ref.: Essig & Hoskins, 1944, Cal. Agr. Ext. Ser. Circ., 87: 78.
Grape rust mite, *Calepitrimerus vitis* (Nal.).
Distribution—Probably wherever grapes are grown.
Injury—Rusting of leaves.
Control—Probably about the same as for the erineum mite.
Ref.: 1942, Bul. Cal. Dept. Agr., 31 (3): 112; Stellwagg, 1931, Anz. Schadlingsk, 7 (7): 73.
Big-beaked plum mite, *Diptilomiopus gigantorhynchus* (Nal.)
Occasionally on grape leaves; see plum.

Grass (Timothy, wild rye, and others).
Cereal rust mite, *Abacarus hystrix* (Nal.)[1]
Distribution—North America, Europe.
Injury—Discolors timothy leaves and kills tip of plant.
Control—Sulfur dust and calcium cyanamide dust.
Ref.: Pepper, 1942, JOUR. ECON. ENT., 35 (2): 201.
Grasspsikelet mite, *Aceria tenuis* (Nal.).
Distribution—Middlewestern States, Europe.
Injury—Deforms spikelets.
Ref.: Ewing, 1922, Proc. Biol. Soc. Wash., 34: 100.

Ivy (Hedera)
Ivy bud mite, *Phytoptus hedericola* K.
Distribution—California.
Injury—Stunts and deforms leaves; especially bad on potted nursery plants.
Ref.: 1943, Bul. Cal. Dept. Agr. 32 (3): 212.

Juniper
Juniper bud mite, *Phytoptus quadrisetus* (Thom.).
Distribution—Eastern United States, Europe.
Injury—Deforms berries and needles; a very similar mite, *Phytoptus cupressi* K., forms terminal swellings on Monterey Cypress in California.
Ref.: 1928, Insects N. Y., Cornell Univ. Mem. 101; 1944, Bull. Cal. Dept. Agr., 33 (1): 19.

Maple
Maple bladder gall mite, *Vasates quadripedes* Shimer.
Distribution—Eastern United States.
Injury—Forms pouch galls on upper-leaf surface, sometimes deforming many leaves (silver maple).
Control—Winter lime-sulfur.
Ref.: Herrick 1935, Insect Enemies of Shade Trees, 199.
Maple spindle gall mite, *Vasates aceris-crumena* (Riley).
Distrubition—Eastern United States.
Injury—Forms elongate galls on upper-leaf surface.
Ref.: Herrick 1935, Insect Enemies of Shade Trees, 202.
(Many other Eriophyids listed on North American Maples.)

Onion, Garlic, Tulip.
Bulb Eriophyid, *Aceria tulipae* (K.).
Distribution—California, Texas, Mexico; Europe.
Injury—Feeds inside bulb layers, causing drying; persists in storage.
Ref.: 1938, Bul. Cal. Dept. Agr., 27 (2): 185: Liro, 1942, Int. Bul. Plant Prot., 16 (9): 118.

Peace, Nectarine.
Peace silver mite, *Vosotes cornutus* (Banks).
Distribution—General in North America.
Injury—Curls and spots young leaves; silvers mature leaves.
Control—The curly-leaf application of lime-sulfur usually controls this mite; sulfur dust on leaves.
Ref.: Essig & Hoskins, 1944, Cal. Agr. Ext. Ser. Cir., 87: 94.

Pear
Pear leaf blister mite, *Eriophyes pyri* (Pgst.)
Distribution—whererever pears grow.
Injury—The typical form blisters leaves and young fruit; the bud form kills flowers.
Control—Lime-sulfur in fall when fruit is off, and with oil in early spring.
Ref.: Essig & Hoskins, 1944, Cal. Agr. Est. Ser. Circ. 87: 99. (Similar mites blister leaves of Mountain Ash, and Service Berry.)
Pear rust mite, *Epitrimerus pyri* (Nal.)[2]
Distribution—General.
Injury—Causes early season browning of the leaves.
Control—Sulfur dust or foliage oil.
Ref.: 1926, Insects of Wn. N. Am.: 50.

Pecan (Hickory also?)
Pecan leafroll mite, *Aceria caryae* (K.).
Distribution—Texas, other Southern States.
Injury—Rolls edges of leaves on upper surfaces, the roll developing spongy structure inside; causes leaf-drop.
Ref.: 1942, Nickels, JOUR. ECON. ENT., 35 (6): 948.

Pine
Pine needle-sheath mite, *Phytoptus pini* Nal.
Distribution—General.
Injury—Causes yellowing and dropping of needles, when severe; said to cause twig-knots in Europe.
Ref.: Walther, 1925, JOUR. ECON. ENT., 18 (6): 830.

Plum, Prune, Cherry
Plum nursery mite, *Vasates fockeui* (Nal. & Trt.)
Distribution—General in Northern United States, Canada; Europe.
Injury—Curls and stunts foliage: rusts older leaves?
Ref.: Putman, 1939, Ent. Soc. Ont. 7th Ann. Rept: 33.
Plum bud gall mite, *Aceria phloeocoptes* (Nal.).
Distribution—Eastern United States: Europe.

[1] Formerly *Callyntrotus hystrix* Nal. or *Epitrimerus hystrix* (Nal.)

[2] The name, *Epitrimerus pirifoliae* K., is based on the pear rust mite as it occurs in California. Until further information is available *pirifoliae* will be suppressed in favor of *pyri* Nal. Ref: Bul. Cal. Dept. Agr. V. 27, No. 3, p. 309, 1938. *Vasates schlechtendali* Nal. is supposed to be on pear but none have been found infesting that host to the best of the writer's knowledge. See apple.

Injury—Deformation of fruit spurs, producing woody galls.
Ref.: 1928, Insects of New York, Cornell Mem. 101.

Finger gall mite, *Eriophyes similis prunianus* Massee.
Distribution—Eastern Canada.
Injury—Forms elongate upper-surface galls on the leaves.
Ref.: Massee, 1930, Ann. Mag. Nat. Hist. Ser. 10, V. 6: 145.

Big-beaked plum mite, *Diptilomiopus gigantorhynchus* (Nal.).
Distribution—General.
Injury—Gradually browns the undersides of the leaves.
Ref.: Putman, 1939, Ent. Soc. Ont. 7th Ann. Rpt: 38.

A leaf vagrant, *Phyllocoptes abaenus* K.
Distribution—California, Ontario.
Injury—None observed so far, but a potential rust mite.
Ref.: 1940, Bul. Cal. Dept. Agr. V. 29 (1): 30.

Pomegranate

Pomegranate leafroll mite, *Aceria granati* (Can.).
Distribution—California, Southern Europe.
Injury—Rolls and stunts the leaves.
Ref.: 1938, Bul. Cal. Dept. Agr. V. 27 (6): 663.

Poplar, Aspen

Poplar bud gall mite, *Aceria parapopuli* (K.).[1]
Distribution—Northern United States.
Injury—Stunts growth by forming woody galls around buds.
Ref.: 1940, Bul. Cal. Dept. Agr. V. 29 (1): 22; 1928, Insects of New York, Cornell Univ. Mem. 101. *A. populi* (Nal.).

Privet

Privet rust mite, *Vasates ligustri* (K.).
Distribution—California.
Injury—Browns leaves; severe infestations curl and stunt the young leaves.
Ref.: 1938, Bul. Cal. Dept. Agr. V. 27 (2): 190.

Privet bud mite, *Aceria ligustri* (K.)
Distribution—California.
Injury—None observed, but mites common.
Ref.: 1943, Bul. Cal. Dept. Agr. V. 32 (3): 213.

Sycamore

Big-beaked sycamore mite, *Rhyncaphytoptus plotani* K.
Distribution—California.
Injury—Browning of the leaves.
Ref.: Essig & Hoskins, 1944, Cal. Agr. Ext. Ser. Circ. 87: 121.

Tomato

Tomato russet mite, *Vasates destructor* (K.)[2]
Distribution—California, Arizona, Colorado; Spain, Hawaii, Australia, New Hebrides.
Injury—The mites cause browning and dying of the leaves and severely russet the fruit: the injury creeps up the stalks, and when the tips are reached the plant dies.
Control—Sulfur dust, either straight or in combination with chemicals for other purposes.
Ref.: Bailey & Keifer, 1943, JOUR. ECON. ENT., 36 (5): 706.

Tomato fungus or erinose mite, *Aceria cladophthirus* (Nal.)[3]
Distribution—Florida: in Ohio greenhouse: Africa.
Injury—Causes excessive hair growth on leaves and stems: known sometimes as white mold.
Ref.: Watson—Fla. Agr. Exp. Sta. Bul. 125, 1914.

Walnut

Walnut erineum[4] mite, *Aceria erineus* (Nal.)[5]
Distribution—Probably wherever English walnut is grown.
Injury—Forms large erineum patches on the leaves but is rarely serious; there may be a bud form of this mite.
Ref.: 1944, Cal. Agr. Ext. Ser. Circ., 87: 131.

Walnut purse gall mite, *Aceria brachytarsus* (K.).[6]
Distribution—California, confined to *Juglans californica* and *J. hindsii*.
Injury—Forms conspicuous purse or bag-like galls on the leaves; where numerous, the leaves are deformed.
Ref.: 1939, Bul. Cal. Dept. Agr. V. 28 (3): 224; Ibid. V. 28, No. 5, p. 328, July 7, 1939.

Walnut petiole gall mite, *Aceria caulis* (Cook).
Distribution—Eastern United States on black walnut.
Injury—Produces large deforming hairy growths on petioles.
Ref.: 1940, Bul. Cal. Dept. Agr. V. 29 (1): 24.

[1] The relationship this bears to *Aceria populi* (Nal.) may be varietal.

[2] See also Massee: Bul. Ent. Res. V. 28, part 3, p. 403, Oct. 1937. The name *destructor* may have to be sunk in favor of *lycopersici* Massee.

[3] The name "*calacladophthora*" is an incorrect spelling.

[4] The approved common name is "walnut blister mite," but the mite forms an *erineum*.

[5] There seems no reason to retain the combination of *tristriatus erineus* Nal. for this mite; see Bul. Cal. Dept. Agr. V. 29, No. 1, p. 24, 1940.

[6] Formerly *Eriophyes tristriatus* (Nal.)

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Effect of Cultivation on Florida Red Scale Populations

MAX R. OSBURN and WILLIS MATHIS, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

In recent years several investigators have reported that the condition of a citrus tree influences the abundance of scale insects found on it. According to Schweig & Grunberg (1936), a grove that is well fertilized and watered is likely to have heavier scale infestations than a poorly kept grove. Thompson (1939, 1942) and Camp [1945] reported that populations of the purple scale, *Lepidosaphes beckii* (Newm.), were higher on citrus trees in which mineral deficiencies had been corrected, and that the principal factors involved in the scale increase were the greater amount of green, succulent foliage on the trees and the increased shading afforded by this foliage.

In 1941, in connection with a study of the effects of cultural practices on the citrus rust mite, *Phyllocoptruta oleivora* (Ashm.), in St. Lucie County, Fla., it was observed that cultivated orange trees were more heavily infested with the Florida red scale, *Chrysomphalus aonidum* (L.), than similar uncultivated trees in the same grove. More recent work has confirmed that observation, and this paper reports the results of a study of the effect of cultivation on Florida red scale populations during the years 1942 to 1944.

EXPERIMENTAL PROCEDURE.—The experimental arrangement consisted of 8 plots of orange trees, each approximately 6 trees wide and 14 trees long, and covering about 1 acre. Four replicates of each treatment (cultivated and uncultivated) were provided during the three seasons. Although the same plots were used throughout the experiment, the treatments were reversed in 1943 and again in 1944, so that the same areas were not cultivated during consecutive years. Each year no two adjacent plots were treated alike.

The cultivation was accomplished by disking one way between the trees and immediately repeating the operation at right angles. Hand hoeing around individual trees followed each disking, because it was impracticable to disk close to each tree. Five cultivations were performed in 1942 and 1943 and four in 1944. In 1942 the plots were given the first cultivation in March and the last in September, in 1943 the first in January and the last in August and in 1944 the first in February and the last in August. A cover crop was grown on the uncultivated plots each season. Aside from the cultivation all the trees from which the data were taken were treated alike. Sulfur was applied several times each year for the control of the citrus rust mite, but no treatments were applied for scale control.

The trees selected for scale sampling were those centrally located in each plot, in order that they would receive the maximum influence of the particular treatment. The data for comparison of the effects of the two treatments on infestation were taken from outer leaves picked at random from each of the 40 trees in each treatment. In 1942 a sample from each tree consisted of 5 leaves, making a total of 200 leaves for the treatment. All living and dead stages of the scale were recorded from the entire surface of each leaf. In 1943 and 1944 the sample from each tree was increased to 10 leaves, making a total of 400 leaves per treatment. In 1943 only the living females (second and third stages) were recorded from lower leaf surfaces, and in 1944 both living and dead females were examined on lower leaf surfaces. The dead scales were classified as "parasitized," "fungused," or "other." At times considerable mortality of the Florida red scale is attributed to a hymenopterous parasite, *Aspidiotiphagus lounsburyi* Berl., and to a species of entomogenous fungus, *Nectria diploa* Berk. & Curt. The recording of these additional data was thought desirable because there might be some question as to the effects of the two treatments on the numbers of scale parasites and the amount of fungus available to attack the scales. During the three seasons, infestations in each treatment were sampled at regular monthly intervals following the first cultivation,

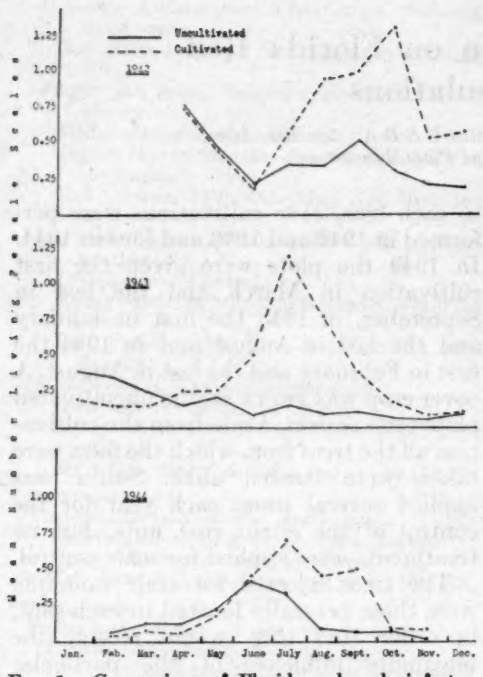

FIG. 1.—Comparison of Florida red scale infestations on cultivated and uncultivated orange trees, St. Lucie County, Fla.

the sampling being continued through December of 1942 and 1943 and November of 1944. For comparison of the infestations during the three years in the two treatments, only living females from lower leaf surfaces were used.

Previous experimental work has shown that inert residues may be responsible for increases in scale populations (Osburn & Spencer 1938). Since in the process of disk cultivation considerable dust and soil may be tossed into the air and may settle on the trees, this deposit was also considered a possible factor contributing to the larger scale populations on cultivated trees. In order to determine the amounts of such deposits on trees in the cultivated and uncultivated areas, four samples were taken from each treatment in October 1943 following five cultivations for the season. Each sample consisted of a composite of 100 leaves from each of 10 trees, or 1000 leaves. Each sample was collected in a large paper bag, brought to the laboratory, placed in a large glass battery jar, covered with water, and allowed to soak for 24 hours. Then each leaf was washed singly in the same water in which it was soaked. The deposit was loosened by rubbing the leaf between the fingers while holding it under water, after which the leaf was discarded. The water containing the material removed from the leaves was poured on a 100-mesh sieve, which screened out the scale insects but allowed the fine soil to pass through. The soil was then filtered from the water and was weighed, after being oven-dried at 57° C. for 24 hours.

EFFECT OF CULTIVATION ON SCALE POPULATIONS.—Comparisons of the mean number of living female scales found at intervals during each of the three seasons on cultivated and uncultivated trees are presented graphically in figure 1.

In April 1942, when samples were examined following the first cultivation, the numbers of scales found in the two treatments were about the same. Infestations dropped in May and June, but the numbers found in the two treatments remained about equal. Beginning in July and continuing through December, infestations were considerably greater on the cultivated than on the uncultivated trees. The greatest difference was in October, when 1.35 scales were found per lower leaf surface on samples from cultivated trees and only 0.30 scale on similar samples from the uncultivated trees. The final cultivation was in September. Later, in November and December, on the cultivated trees the infestations were found to have dropped considerably, but still remained more than twice as high as those on the uncultivated trees.

In January 1943, immediately following the first cultivation for that season, a few more scales were found on the uncultivated than on the newly cultivated trees, and this continued to be true until the end of March. Such a condition was not unexpected because, as stated above, the uncultivated trees were the same trees that had been cultivated in 1942, and the difference in the infestation resulting from the treatments that year was reflected for a short period in 1943. In April and May the infestation increased slightly on the cultivated trees but decreased on the uncultivated ones, and there was very little difference between the number of scales found in the two treatments. From the first of June through September infestations were much greater on the cultivated

trees. The greatest difference was in July, when 1.22 scales per leaf were recorded from the cultivated trees and only 0.15 scale from the uncultivated ones. The last cultivation for the season was performed in August, and infestations on the cultivated trees gradually fell until in November and December there was no difference between the two treatments. After March the scale infestation on the trees in the uncultivated plots was low, and it remained approximately the same through the remainder of the year.

In 1944 the first cultivation was in February, and from then until the end of June the infestations in the two treatments were about equal, both increasing to about the same extent in May and June. In July the number of scales increased in the cultivated area and decreased in the uncultivated one. There was a decrease which continued until August, and from then through November infestations remained about the same. The greatest difference between treatments was found in September, when a mean of 0.50 scale was recorded from the cultivated and 0.07 from the uncultivated trees. The last cultivation was performed in August, and in October and November infestations on trees that had been cultivated dropped to about the same level as those on uncultivated trees. Differences between treatments were not so great in 1944 as in either 1942 or 1943.

Infestations in the cultivated plots reached their greatest numbers in October in 1942 and in July in 1943 and 1944. On the uncultivated trees, after the experiment for each season was well under way, the greatest numbers of scales were found in September in 1942, in July in 1943, and in June in 1944. Infestation peaks in both treatments appeared later in the season in 1942 than in 1943 or 1944. Even though considerable differences in infestation were found each summer or early fall between the cultivated and uncultivated trees, in the winter the populations on the cultivated trees dropped to about the same level as on the uncultivated ones. This dropping of population in the cultivated plots may have been caused by a definite slowing of scale development and reproduction due to cool weather, the increasing dormancy of trees causing them to have less succulent foliage, and probably by unknown natural factors.

EFFECT OF CULTIVATION ON PARASITES AND FUNGI.—The percentages of second- and third-stage female scales found parasitized or attacked by entomogenous fungi in the two treatments during the 1944 season are presented in table 1.

Table 1.—Florida red scales parasitized and fungused, St. Lucie County, Fla., 1944.

Month	Scales Parasitized		Scales With Fungus	
	On Cultivated Trees	On Uncultivated Trees	On Cultivated Trees	On Uncultivated Trees
	Per Cent	*Per Cent*	*Per Cent*	*Per Cent*
March	6.2	11.9	0.7	2.0
April	8.1	15.9	8.1	3.3
May	.7	4.7	3.1	6.5
June	2.8	3.0	.3	2.2
July	11.4	8.8	1.4	2.8
August	3.2	.6	6.8	11.9
September	3.1	1.2	19.1	20.7
October	1.5	1.9	27.3	22.8
November	2.6	3.1	32.0	30.2

There was very little difference between the percentages of scales found parasitized in the two treatments on any one date. They were slightly higher in the uncultivated plots in March, April, and May, but in July, August, and September the reverse was true. The slight differences at different periods of the year in each treatment might be attributed to greater living-scale populations available for parasitization rather than to a direct effect of the cultural treatments on parasite development.

There was practically no difference between the percentages of scales attacked by fungi in the two treatments on any one date. Percentages of fungused scales in both treatments were considerably greater later in the season than they were in the beginning. These data indicate that neither the cultural practice nor the number of scales in the treatment affected the percentage attacked by the entomogenous fungi.

EFFECT OF CULTIVATION ON DEPOSITS OF DUST AND SOIL ON TREES.—The amounts of inert deposits of soil or dust obtained from 4 samples of 1000 leaves from each treatment in October 1943 are given in table 2. It is very doubtful

Table 2.—Soil and dust deposits found on leaves of cultivated and uncultivated orange trees, St. Lucie County, Fla., 1943.

SAMPLE[1]	CULTIVATED TREES	UNCULTIVATED TREES
	Grams	*Grams*
1.....	2.1	2.0
2.....	3.4	1.0
3.....	.5	2.4
4.....	3.5	3.2
Total.....	9.5	8.6

[1] Each sample contained 1000 leaves.

whether the slightly greater amount found on the samples from cultivated trees was entirely responsible for the large differences in scale populations between the cultivated and uncultivated trees.

EFFECT OF CULTIVATION ON TREES.—The intensive cultivation during each of the three years stimulated the trees to a marked degree. The trees put on more growth, developed more green leaves, grew larger, and generally appeared to be in better physical condition than the uncultivated trees, even though the cultivated trees were more heavily infested with the Florida red scale than were the uncultivated ones.

SUMMARY AND CONCLUSIONS.—A comparison has been made of the numbers of the Florida red scale, *Chrysomphalus aonidum* (L.), found on orange trees growing in cultivated plots and on those growing in plots not under cultivation in the same grove. There were markedly greater scale infestations on trees growing under cultivation than on uncultivated trees.

The differences in the percentages of parasitized scales and entomogenous fungi found in the two treatments were very small. There was some evidence that a greater percentage of parasitization was associated with the larger living-scale infestations, but this was not true of the percentages of fungus affected scales found in the two treatments.

Disk cultivation increased the deposit of soil or dust on leaves very slightly. Orange trees subjected to intensive cultivation were more vigorous and in better physical condition than those left uncultivated, even though they were infested with more scales.

It is concluded that tree stimulation, a result of cultivation, was the most important factor in the development of scale infestations.

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AT THE AAAS MEETINGS

A special meeting of the Cambridge Entomological Club will be held in conjunction with the meetings of the A.A.A.S. in Room B-455, Biological Laboratories, Harvard University, Cambridge, Massachusetts at 8 P.M. Thursday, December 26. The meeting will be addressed by Professor Clarence H. Kennedy of Ohio State University. The subject of the address will be "The Child-Labor of the Termites versus the Adult-Labor of the Ant Society." An informal social gathering will follow. Visitors will be welcome.

The Sunflower Moth and Some of Its Natural Enemies

A. F. Satterthwait and R. B. Swain, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

An investigation of the insects affecting the common sunflower, *Helianthus annuus* L., and other plants of the genus *Helianthus* was initiated in 1927 by the senior author. At that time the Southeast Missouri Sunflower Growers' Association, growing 5000 acres of sunflowers annually, desired aid in the control of insects attacking this crop. About a year previously the Hershey Company had begun to produce them for oil in Cuba, and by 1932 had about 73,000 acres in sunflowers. By September of that year the sunflower moth, known also as the flower webworm, *Homoeosoma electellum* (Hulst), (Drake & Harris 1926) had destroyed about 500 acres, limited to Havana and Matanzas provinces, and had completely ruined the crop from some small fields.

At the request of the Hershey Company, S. C. Bruner, head of the Cuba Agricultural Experiment Station, undertook to utilize the natural enemies of this insect in its control. Arrangements were made with the United States Department of Agriculture to have a rapid survey made of sunflower moth parasites in the United States with the purpose of finding a promising species, easily reared, which might be introduced into Cuban sunflower fields. Only one hymenopterous parasite, *Apanteles homoeosomae* Mues. (1933), and one dipterous parasite, *Nemorilla floralis* (Fallen), were known to affect this pest in Cuba, and neither of these appeared to be important. This work was undertaken at the Webster Groves, Missouri, laboratory of the Bureau of Entomology and Plant Quarantine, the Hershey Company providing the services of the junior author during 1933. The information on the biology of the sunflower moth and its parasites, and the comparative importance of the latter, obtained during these studies, is summarized in the present paper.

Distribution and Host Plants.—In the course of these studies the sunflower moth was found to be destructive to the sunflower crop in Cuba, and in the Mississippi Valley from Louisiana to Missouri and Illinois. In these areas it is one of five decidedly destructive pests of sunflower. In Cuba sunflower growers regard it as their only serious pest. In the field the injury caused by this insect is more conspicuous than that due to any other species.

In Missouri the earliest host plant found in the spring was *Coreopsis grandiflora* Hogg. Then came the ornamental sunflowers, *Heliopsis helianthoides* var. *pitcheriana* Fletcher, *Helianthus annuus*, *H. tuberosus* L. (Jerusalem artichoke), a hybrid *Helianthus* the flowers of which resemble dahlias, and *Verbesina encelioides* B. & H.

Mr. Bruner reported that the most important weed host in Cuba was *Bidens pilosa*, known there as romerillo blanco, and that it was not heavily infested.

Drake & Harris (1926) recorded the following host plants in Iowa: African marigold, *Tagetes erecta;* French marigold, *T. patula;* golden wave, *Coreopsis tinctoria;* crown of gold, *C. coronata;* tickseed, *C. lanceolata;* orange coneflower, *Rudbeckia fulgida;* camomile, *Anthemis tinctoria kelwayi;* and *Helianthus.*

Life History and Habits.—The egg of this moth is pearly white, elliptical, finely reticulated, from 0.63 to 0.80 mm. long, and from 0.23 to 0.27 mm. in diameter.

The larva attains a length of about 19 mm. It is purplish or reddish-brown with four longitudinal light blue-green stripes on its back.

The pupa is about 10 mm. long and is reddish-yellow. It is slender, polished, and without spines. A few fairly long setae occur about the caudal end.

The adult is about 11 mm. long at rest. The wing spread is about 21 mm.

The moth places her eggs singly or in small groups among or within the sunflower florets, even within the tube formed by the united anthers. As the florets are close-set, eggs laid between them are nearly as well protected as those laid within them. The eggs laid in *Coreopsis* heads are similarly placed. Mr. Bruner obtained as many as 91 eggs from 1 female. A female lays the majority of her

eggs during a single day. The egg stage requires from 40 to 72 hours.

Five instars were observed, the first requiring less than 4 days, the second 3 to 5 days, the third about 5 days, the fourth 1 to 3 days, and the fifth 10 to 12 days. A series of individuals was carried through in cages from oviposition to issuance of adults, using eggs laid on or after September 12.

From its earliest activity the larva lays its delicate silk over the face of the composite flowers. In the early instars about eight times as many larvae feed on the florets as on the kernels. The silk binds the dying parts of the florets with the larval frass, giving the flower an exceedingly trashy appearance. By the time the larva is large enough to be readily seen, it has formed and is living within a tube of silk, which is usually tinged with green.

As the achenes develop, the larva eventually feeds on them. It may cut a hole about 0.8 mm. in diameter or larger into the achene or achenes penetrated. In *Heliopsis helianthoides* var. *pitcheriana* the larvae were found tunneling the receptacle and occupying the hollow stalk beneath it. Infestations frequently are heavy enough to destroy all the seed in a single flower head, especially where there is only one head to a plant.

When the larvae have finished feeding, they migrate in haste to find acceptable places in which to pupate. Whether after migrating they cut into the achenes, or whether only some of them make such migration was not determined, but in the field as well as in the cages this behavior was conspicuous. Actively migrating larvae have been observed not only upon the heads, but also on the leaves and stalks, and hanging by threads of silk from various parts of the plants.

The full-grown larva constructs a tough, open-mesh, close-fitting cocoon, from which it is almost impossible to remove either the larva or the pupa without injury. The cocoon may be in a silken tunnel among the achenes or within a single achene.

Adults were observed in the field from June 28 to September 4, and were issuing in cages until November 5. Many larvae were taken June 17. Although no winter collections were made that would prove the manner of overwintering, it is assumed that either the larval or the pupal stage is the hibernating form, as adults issuing November 5 were presumably forced by laboratory heat, and as many larvae taken June 17 yielded adults June 28. No form was successfully carried through the winter. The time from oviposition to issuance of adult was about 24 days in midsummer on outdoor-growing plants, and about 34 to 38 days in midsummer and autumn in cages. Thus, in the vicinity of St. Louis there might be at least four complete broods. The first-generation moths must have been in flight about May 15 to 21; the second, about June 28; the third, about August 2; and the fourth, about September 4.

In Cuba, Mr. Bruner studied the life cycle from September to February. In September the last larval stadium required only 3 days and the pupal stage 4 to 8 days. The life cycle was 24 to 26 days. In November-December the pupal stage lengthened to 10 to 12 days, and in late January 6 to 29 days in the laboratory. In December the last larval stadium ranged from 4 to 17.5 days. Adults were kept alive from 6 to 17 days, being fed with flowers and sugar. Although the weather at Havana is mild all winter, the activity of this insect practically ceased in December. Mr. Bruner construed the increased time in the larval stage during the winter as evidence that this was normally the overwintering stage. Infestation in Cuba was heavy in September 1932 and light in June 1933. The infestation in September 1932 was the first noticed.

OBSERVATIONS ON PARASITES.—The survey to obtain parasites of the sunflower moth for propagation and shipment to Cuba was confined to a 6-month period from April to mid-September 1933. Search was made on Compositae in the Missouri Botanical Garden and other flower gardens in and near St. Louis before the commercial sunflower crop or wild sunflowers were in bloom. The first sunflower moths were collected in *Coreopsis grandiflora* on June 17. About 200 heads were collected from this host in one garden in Webster Groves, where 75 per cent of the heads were infested, some of which contained as many as 6 larvae.

By July 10 the sunflowers were blooming, and collections were made in the

St. Louis area in Missouri and Illinois, in southeastern Missouri, and at Covington, Louisiana. Larvae from these collections were caged individually in glass vials for issuance of parasites, and later for parasitization by adult parasites. An effort was made to secure nonparasitized larvae by bagging sunflower heads before they flowered and introducing adult moths after the florets had opened. No eggs or larvae were obtained by this method, however, and field-collected larvae were used successfully as hosts on which to rear parasites in cages without confusion of parasite species.

Pairs of adult parasites were caged in 28 by 100 mm. glass vials or in wire-screen cages for observation of matings and of responses to host larvae introduced for parasitization. Water was furnished either as succulent sunflower plant tissue or as water-soaked cotton in a 9 by 35 mm. tube. Honey was furnished in a tiny vial filled with cotton, or within a split sunflower achene placed inside the cage. Adult parasites were placed in an electric refrigerator during hot nights, or for longer periods. The development of parasites in the pupal stage was delayed by refrigeration or speeded up by incubation at 83 to 86° F.

Sunflower moths of varying sizes and stages were offered to the parasites for oviposition. They did not seem to be interested in the first three instars. To expose larvae to parasites for stinging, it was found convenient to transfer the adult parasites, and leave the larvae undisturbed in their exposure cages. Shell vials with ordinary corks were generally used and proved very satisfactory.

Lixophaga variabilis (Coq.) is a small larvaevorid fly about the color and proportions of the housefly, but decidedly smaller. It was not a frequent parasite of the sunflower moth, but an abundant parasite of a sunflower budworm, *Suleima helianthana* (Riley), and was reared from this host in sunflower in the St. Louis and in the southeastern Missouri areas from June to October, and from the budworm in Jerusalem artichoke in the St. Louis area from August to October.

No deposition of eggs or larvae was observed. The full grown larva, which is about 5 mm. long and 1.2 mm. in diameter emerges from the host larva and forms its puparium. In nature the larva probably buries itself in the soil to pupate. As a rule only one larva of this parasite develops in one host. In one instance, however, it seemed certain that two larvae had developed and issued simultaneously from one host. The reddish-brown puparium is about 5.5 mm. long and 2.5 mm. in diameter.

Anachaetopsis tortricis (Coq.) is a small larvaevorid fly about the size of *Lixophaga variabilis*, but with a darker, more glossy surface. It was reared abundantly from sunflower moth larvae collected from *Coreopsis grandiflora*, *Heliopsis helianthoides* var. *pitcheriana*, and sunflowers in the St. Louis and the southeastern Missouri areas. Adults issued from June 30 through October 11. No oviposition was observed. Several gravid females were dissected. Eggs which seemed ready for deposition were ovoid, about four times as long as thick, with one contour straight and the other convex. There was no evidence that larvae might be deposited. The maturing larva takes a position in the host pupa which permits the caudal spiracles of the larva to protrude beneath the tips of the wing pads of the host. These spiracles form a prominent Y. The host pupates before being killed by the parasite and the host pupal shell retains the fly puparium. There is only one parasite to each host. The time required for development was not learned. However, one late-summer parasite became adult 50 days after the host was caged. The host larvae, which on examination showed no visible sign of parasitization, yielded adult parasites 16 days later.

A large number of specimens of this parasite issued at one time and were placed in a cylindrical wire cage 12 inches in diameter and 24 inches tall to permit mating and flight. The cage was set over water and was draped with wet towels to supply humidity. Several other specimens were caged on the head of a sunflower growing in the garden. Though the species mated freely, no oviposition or parasitization was accomplished.

Leskiomima tenera Wd. is an internal parasite belonging to the larvaevorid fly family. It was reared from several larvae of the sunflower moth collected in sunflowers at Caruthersville, Missouri, August 4 and 31. The parasite forms its

puparium normally within the skin of the host larva. One parasite issued from the August 4 collection, 10 from that of August 31. Adults issued from August 31 to October 6. Thus, this species seems narrowly adapted to hosts and to season. In one instance the length of the pupal period was between 28 and 36 days and in another it was between 9 and 18 days. There is only one parasite to each host.

The puparium is about 5.77 mm. long and 2.15 mm. in diameter. At the middle it is terete, and the ends are somewhat depressed.

The adult has a rufous body and face, and gray dorsum of thorax. It is about 6 mm. long.

Siphophyto floridensis Towns., another larvaevorid fly, is a frequent parasite of the sunflower moth, the sunflower budworm, and the iris seed-pod tortricid *Endothenia hebesana* (Wlk.). Hosts were collected in the sunflower, the Jerusalem artichoke, *Coreopsis grandiflora*, and *Iris germanica* L. in the St. Louis area and in southeastern Missouri.

Adults issued from June 20 to October 31. The adult is 5 to 6 mm. long with wing expanse about 10 to 12 mm. Its color is a brownish gray. The proboscis is very slender, nearly one and a half times as long as the head is wide, with the distal end curved down. Only one larva develops in the host. The larva issues from the skin of the host and forms its puparium in contact with the host and within the host's silken cocoon. The larva leaves the host in about 7 to 11 days. The puparium is about 5.5 mm. long, with caudal spiracles small, close-set and only slightly protruding. Nine days elapse between the formation of the puparium and the issuance of the adult. From 16 to 20 days is sufficient for development from oviposition to issuance of adult. Infested hosts were reared and 120 puparia observed. Several adults were caged together and provided with host larvae to secure deposition of eggs. No mating was observed and no eggs were obtained.

Microbracon mellitor (Say), a rather general parasitic wasp, was frequently obtained from collections of insects infesting sunflowers. It was reared from larvae of the sunflower moth collected from sunflower in the St. Louis and southeastern Missouri areas; and from *Heliopsis helianthoides* var. *pitcheriana*, *Verbesina enceliodes*, and *Coreopsis grandiflora* in the St. Louis area. It was also reared from larvae of the sunflower head cutworm, *Stibadium spumosum* Grt., and from unidentified hosts in sunflowers in southeastern Missouri. Adults issued from July 27 to September 12 and some of them lived until November 20. One adult lived from September 8 to December 1. Only one parasite was reared from each host.

The adult female is about 4.5 mm. long, not including the ovipositor, which is nearly as long as the abdomen. The insect is yellowish red.

The larva feeds externally upon the body of the host larva and spins a silken cocoon varying in color from white to brown. It is about 4.5 mm. long and 2 mm. thick. Only one parasite to a host was recorded. Larvae were observed to separate from the host remains before spinning their cocoons. One larva was noted as small when first seen and large 2 days later. After 7 more days the adult issued. Thus the pupal stage was about 5 days.

Larvae of 61 sunflower moths, 1 *Laspeyresia caryana* (Fitch), 1 *Carpocapsa pomonella* (L.), and 3 unidentified Microlepidoptera were exposed to females of *Microbracon mellitor* for oviposition, but none were stung. Several cages, each containing a single pair of adults, were made up, but no mating was observed.

Two *Microbracon nuperus* (Cress.) adults issued June 29 from infested heads of *Coreopsis grandiflora* collected at Webster Groves, Missouri, on June 17, 1933. Although these parasites were not discovered associated with their hosts, no possible hosts were found other than the sunflower moth larvae, and these were extremely destructive to the collected flower heads.

Chelonus altitudinus Vier. proved to be a parasite of the sunflower moth and the sunflower head cutworm. This hymenopterous parasite was reared from sunflower moth larvae collected in the St. Louis area in July and in southeastern Missouri in August, and from the sunflower head cutworm collected at Caruthersville, Missouri, on August 31. Only one parasite developed in each host.

The adult is about 4 mm. long, robust, and black. Several cages were made up with one male and one female in each for

breeding, but no matings were observed. In all, sunflower moth larvae were offered three times, *Feltia subgothica* larvae twice, and unidentified microlepidopterous larva once, but no parasitization was obtained.

Apanteles homoeosomae Mues. was an active parasite of the sunflower moth in sunflowers both in Cuba and in the Mississippi Valley. Specimens were submitted to the Bureau of Entomology and Plant Quarantine by the junior author, and to the National Musem by S. C. Bruner, and to each inquirer the species was reported as new. It was later described by C. F. W. Muesebeck (1933).

Specimens were reared from sunflower moth larvae and from unidentified host larvae collected in southeastern Missouri, in August and September.

The adult female is mostly black and about 2.5 mm. long, exclusive of the ovipositor which is about as long as the abdomen. The cocoon is white, about 4.5 mm. long. The larvae left their hosts and spun their cocoons at about the eighth day. Only one parasite developed in each host larva.

Either 10 or 11 females and more males were reared from the field-collected host larvae, and 66 host larvae were caged with them for parasitization; 55 stings were observed. Parasites developed to the cocoon stage in 22 larvae, from 4 of which adults issued, 1 male and 3 females. The period from oviposition to issuance of adult was about 12 days. Some of the adults lived about a month.

Bassus buttricki Vier. was recovered frequently from insect-infested sunflowers. It was reared from both sunflower moths and budworms collected from sunflowers in August to October in southeastern Missouri, and from budworms taken from *Verbesina encelioides* at St. Louis. Of 43 males and 24 females reared, 28 were from undetermined hosts. Adults issued from July 17 to September 29.

The body of the adult is about 4.6 mm. long, the antennae are about 3.6 mm. long, and the ovipositor is as long as the thorax and abdomen together. The larva is white, with pellucid dots. When it has finished feeding, the larva constructs a whitish silken cocoon about 5 mm. long and 2.25 mm. thick. Only one parasite normally develops from a host. The time from oviposition to issuance of the adult is about 21 days. The pupal stage is sometimes less than 7 days. A number of cages were made up with one male and one female each, and were offered host larvae. Four pairs were observed to mate, but no stinging was observed.

Macrocentrus ancylivorus Roh. is an occasional parasite of the sunflower moth and the sunflower budworm. From a collection of infested *Ambrosia artemisiifolia* L. (ragweed) growing at the edge of a sunflower field, numerous *M. ancylivorus* adults issued, at least one of which was from a larva of the sunflower budworm. Specimens of this parasite were reared from the same host species infesting heads of Jerusalem artichoke and sunflowers collected at Cross Keys, Missouri, and at southeastern Missouri, respectively. Only one parasite develops in one host larva. The mature larva leaves the body of the host and spins a silken cocoon.

Angitia n. sp. was reared from 9 collections of the sunflower moth larvae in 1933. Of these collections 2 were from *Coreopsis grandiflora* at Webster Groves, Missouri, in June, 3 from sunflower in the St. Louis area, and 4 from sunflowers in southeastern Missouri. Sunflower moth larvae and two naked bagworm larvae, *Thyridopteryx ephemeraeformis* (Haw.), were exposed to adult parasites issuing from the first four collections. In all 433 sunflower moths, 9 sunflower budworms, and 2 bagworm larvae were subjected to the selective action of females of this parasite; 270 sunflower moths were seen to be stung, but no larvae of the other two species.

Only one larva of *Angitia* n. sp. issues from one host larva. It is white when it issues. The spinning of the cocoon begins promptly and may require 2 or 3 days for completion. The finished cocoon is about 8 mm. long and 3 mm. thick. Its color varies from light tan to nearly black. The female is about 10 mm. long, including the ovipositor. The male is about 6.5 mm. long. In both sexes the general color of head, thorax, and abdomen is black, and that of the legs honey yellow. From oviposition to issuance of the larva required 9 days or less, and from oviposition to the issuance of the adult about 20 days.

Nineteen adults, consisting of five males and 13 females and one of which the sex was not noted, were reared from

hosts parasitized in the field. Three adults, reared indoors, were used in the breeding project. On October 19, 1933, 44 cocoons were sent to Mr. Bruner for rearing and release in Cuba. Delivery required 4 days. Twenty-eight adults issued, two of which died en route; all were males. The average longevity of these parasites was 23 days, the maximum 61 days. These adults were kept in corked 25 by 90 mm. vials, in an ordinary refrigerator, except for daily examination involving about 30 minutes. For food, honey was placed in a split hull of sunflower seed and pinned to the cork.

Cremastus epagoges Cush. adults were reared from larvae of the sunflower budworm collected from *Ambrosia artemisiifolia* at the side of a sunflower field at New Madrid, Missouri, on August 25, 1927, and from larvae of the sunflower moth in sunflowers in southeastern Missouri in August and September. The female is nearly 7 mm. long and the ovipositor is about three-fourths as long as the abdomen. The species is very slender and the legs are long. Neither mating of the parasites nor stinging of subjected larvae was observed.

One adult *Perilampus similis* Cwfd., almost certainly a secondary parasite, issued from a cocoon attached to a sack of sunflower heads infested mainly by the sunflower moth. The cocoon was without host remains. The collection was made at Sikeston, Missouri, on September 29, at a time when the sunflower moths were excessively numerous and very active, and it seems most probable that the sunflower moth was the primary host.

OTHER NATURAL ENEMIES.—*Hydnocera pubescens* Lec. is a predator in both the larval and the adult stages. It belongs to the family Cleridae. Larvae of this species occurred in the St. Louis and the southeastern Missouri areas in sunflowers in July, August, and September, and in *Heliopsis helianthoides* var. *pitcheriana* at St. Louis on July 17. The larvae were observed feeding on both larvae and pupae of the sunflower moth and on an immature larva of the sunflower budworm. Adults were observed to be present in the field from August 26 to October 10. The adult is about 4 mm. long, dark blue and hairy, and its elytra entirely cover the abdomen. The third thoracic segment and abdominal segments 1, 4, and 5 of the larvae are nearly maroon to whitish yellow on the dorsum and sides. In shape this larva is much like *Chauliognathus marginatus* (F.).

Metarrhizium anisopliae (Metsch.) is an entomogenous fungus effective in controlling insect outbreaks under favorable conditions of moisture and temperature. It was found affecting a sunflower moth larva collected at New Madrid, Missouri, on July 28.

SUMMARY.—At the request of sunflower growers in Cuba, through its Agricultural Experiment Station, a study was undertaken at the Webster Groves, Missouri, laboratory of the Bureau of Entomology and Plant Quarantine, to find a parasite of the sunflower moth, *Homoeosoma electellum* (Hulst), suitable for introduction into the sunflower fields of Cuba. This study involved a survey of the distribution of the moth and its host plants in the United States, and of its life history and habits. The search for parasites was made in Missouri, Illinois, and Louisiana. The single predator, *Hydnocera pubescens* Lec., and the following 12 insect parasites were reared: *Lixophaga variabilis* (Coq.), *Anachaetopsis tortricis* (Coq.), *Leskiomima tenera* (Wd.), *Siphophyto floridensis* Towns., *Microbracon mellitor* (Say), *Microbracon nuperus* (Cress.), *Chelonus altitudinus* Vier., *Apanteles homoeosomae* Mues., *Bassus buttricki* Vier., *Macrocentrus ancylivorus* Roh., *Angitia* n. sp., and *Cremastus epagoges* Cush.

Angitia n. sp. was reared in numbers, and 44 cocoons were sent to Cuba in October 1933; 28 males issued. Examination of the dead forms showed that all were males.

Metarrhizium anisopliae (Metsch.) an entomogenous fungus, was also found affecting the sunflower moth larvae collected at New Madrid, Missouri.—8-1-46.

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Rapid Vacuum Fumigation of the Body Louse with Methyl Bromide

PHILIP C. STONE,[1] and DELMON W. LAHUE,[1] *Sanitary Corps, Army of the United States*

During the course of World War II it became evident that the entry of large numbers of Prisoners of War into the United States and the return of American personnel from foreign countries might introduce serious diseases into the country. One of the most important of such diseases is epidemic typhus fever which was known to be widespread in Europe, Asia, and Africa.

It is definitely known that the *Rickettsia* causing epidemic typhus fever is transmitted by human body live. It is probable but not certain that it is also transmitted by the human head louse. To the best of our knowledge the louse itself is not affected by the *Rickettsia* and is merely a carrier. The exact mode of transmission of the disease is not entirely clear. It is known, however, that *Rickettsia* can be recovered from the blood stream of an active case. The louse ingests some of these organisms when it bites an infected individual and the *Rickettsia* seem to live and multiply in its gastrointestinal tract. The body louse deposits these organisms with its feces when it travels around the body of a healthy individual on whom it feeds. The bite of the louse causes intense itching and when the individual scratches he rubs in some of the infected louse feces and the *Rickettsia* probably penetrate his body through the scratch abrasions. It is considered possible that *Rickettsia* may also penetrate the lining of the respiratory tract through the inhalation of dried powdered louse feces. Certain cases seem definitely to have been infected in this manner.

The habits of the body louse and of the head louse are quite different. The former lives in the clothing of an infested individual and invades the surface of the body itself only to feed. The eggs are laid in the seams of the clothing. The head louse lives, feeds, and breeds among the hairs on the scalp. Its eggs are attached to the shafts of the hairs of the head near the scalp. The third type of louse which infests humans is the small pubic louse, commonly known as the crab louse. Its habits are similar to those of the head louse except that it lives only around the body and face hairs. To the best of our knowledge it does not transmit disease and is merely a nuisance.

The life habits of the three types of lice indicate the methods which must be undertaken to eradicate them. Various types of insecticides are effective against the head and pubic lice. Obviously, to eradicate body lice all clothing and equipment must be completely disinfested in a manner which will kill all adult forms and eggs. The classic method by which this may be accomplished is by the use of steam, either live or under pressure, and the method is highly effective. However, woolen garments and leather and rubber goods are usually ruined by the procedure. Anyone who served in Europe during World War I can recall the condition of his clothing after it had been disinfested in a steam unit. With this in mind the Surgeon General directed that methyl bromide gas be used as an alternative method whenever possible. The Department of Agriculture had done considerable work with this gas for the disinfestation of grain and greenhouses and methyl bromide had proved to be a very effective louse killer, destroying both adult forms and eggs. It does not kill the lower organisms such as bacteria and *Rickettsia*. Consequently should an actual case of typhus fever be encountered pressure steam will always be necessary.

The Surgeon General specified that at ports of embarkation in the continental United States all prisoners of war were to be completely disinfested by either steam or the methyl bromide technique. It was further directed that all incoming American personnel should be examined for louse infestation and that if any lice were found that individual and all of his contacts should be disinfested. Due to the effectiveness of DDT powder overseas it never became necessary to disinfest all inbound personnel as a routine practice.

The original plant constructed at the

[1] Captain, Sanitary Corps, Army of the United States.

Hampton Roads Port of Embarkation, Newport News, Virginia, was designed for the use of methyl bromide at atmospheric pressure. The wooden fumigation chambers were patterned after those used by the Department of Agriculture but they did not prove satisfactory for the heavy duty encountered at a port. Methyl bromide is a highly penetrating gas at ordinary temperatures and it was obvious that tightly locked metal chambers would be necessary. Vacuum operating against live rubber gaskets produces a tight joint in the simplest possible fashion. Furthermore, it was the feeling of all concerned at the port that vacuum would increase the penetration of the gas into the clothing bundles and would enhance the activity of the gas. This would in turn allow for a reduced time of exposure to the gas and would introduce a method by which the gas could be rapidly eliminated from the bundles.

The present work was undertaken to investigate the possibilities inherent in the use of methyl bromide gas in a high vacuum for the elimination of the human body louse in both adult and egg stages.

Originally the Office of the Surgeon General recommended, for atmospheric fumigation of body lice, a 30 minute exposure to 1 pound of methyl bromide gas per 100 cubic feet when the temperature of the clothing was above 70° F. These specifications were followed in the vacuum fumigation of louse infested clothing until criteria for the vacuum method could be determined. Tests were begun with methyl bromide gas in the vacuum fumigation of all stages of body lice to reveal the necessary information for fumigating louse infested clothing under various conditions, and to determine whether the 30 minute exposure period could be safely reduced.

An effort was made in conducting these experiments to approximate the temperature conditions encountered during the fumigation of clothing at this port. It proved impossible to attain completely uniform temperature conditions for all experiments, but the experiments reveal a fundamental working picture of what can be expected in the rapid vacuum fumigation of body lice when different dosages of methyl bromide gas are used under seven separate exposure periods.

The time of exposure to the gas was an extremely important factor since thousands of prisoners arrived with each convoy. The capacity of the original disinfestation plant using atmospheric fumigation had been estimated at 150 men an hour. By changing to vacuum fumigation and rearranging the plant an average of 550 men per hour were deloused by routine over 24-hour periods during warm weather. This vacuum fumigation procedure so effectively deloused the clothing and equipment of 131,451 German and Italian prisoners of war that no lice were reported reappearing on these men.

APPARATUS AND EXPERIMENTAL PROCEDURE.—Since steel was not available, for building the fumigation chambers[1] during the summer of 1943, six 300-cubic foot cylindrical submarine net buoys, 12 feet long and 5 feet 9 inches in diameter were procured from the Navy. These tanks were remodeled for vacuum fumigation chambers as shown in figure 1. A hinged, free swinging door with a live rubber gasket was fitted to one end. The bulkhead in the center of each cylinder was cut away. Thirteen inches of concrete was poured for the floor leaving a total air capacity for the chamber of 261 cubic feet. Each chamber was equipped with the following: a sheet steel ramp, 2 inch breaker valve, 6 inch ventilator shaft with centrifugal exhaust fan, electrical connections and light, two 8 inch circulating fans, 49 feet of hot water heating pipes, immersion thermometer, vacuum gauge, gas introduction apparatus and two 2.5 inch vacuum exhaust openings. The chambers were insulated on the outside with 2 inches of canvas covered asbestos. Each chamber accommodated three slatted fumigation carts, 32×33×39 inches and each cart held the clothing of 20 men.

The vacuum pump used in these experiments had an 11-inch stroke; a 24-inch cylinder head and was driven by a 60-horse power electric motor. A slightly smaller pump was maintained at all times for emergencies.

Preliminary tests with lice eggs flown from Florida[2] had revealed that all ages

[1] The authors are particularly indebted to Colonel Thomas M. Lowry, Medical Corps, Army of the United States, Port Surgeon, Hampton Roads Port of Embarkation, who originally planned and supervised the construction of the vacuum chambers for fumigating body lice with methyl bromide.

[2] Original cultures of lice were furnished through the cooperation of Dr. E. F. Knipling, Senior Entomologist, Bureau of Entomology and Plant Quarantine, Orlando, Florida.

of eggs were not equally resistant to the gas. Consequently it was necessary to rear lice for these experiments. The louse colony was divided into three groups—eggs, nymphs and adults, and was held in an incubator at 27° to 29° C. Each morning before the lice were fed, the adults were transferred to clean pieces of cloth and the eggs laid during the previous 24 hours were placed in a dated container and incubated until used. The active stages were fed twice daily for 20 minutes by placing the squares of cloth containing the lice on the back of a man.

Approximately 100 engorged nymphs and adults and 200 eggs from each collection of eggs laid daily during the previous 6 days were used in each experiment. To prevent eggs or active lice from scattering from the cloth during fumigation, each of the seven groups was wrapped in six thicknesses of cheesecloth and placed in a separate numbered cardboard container. The top and the bottom of each container was perforated with six quarter-inch holes for ventilation. The eggs and lice so prepared were kept in the incubator prior to some experiments. For other experiments, they were chilled at 6° C. for 24 hours before fumigation.

All equipment worn and carried by each man who was to be disinfested was packed in a separate numbered barracks bag and deposited in a fumigation cart as part of the routine disinfestation procedure. In order to force the gas to penetrate a greater depth of clothing in the experiments than in the regular delousing procedure, the seven test containers were placed in the center of 60 clean army blankets in the same type of fumigation cart. The blankets when folded four ways completely filled a cart. There were 16 inches of blankets above, below and on either side of the test containers of lice, or an equivalent of 120 layers of blankets on all sides in each experiment. This was actually much greater protection to the lice than was encountered under working conditions.

Duplicating as closely as possible temperatures encountered during seasonal variations, blankets were placed in fumigation carts and held in a heated chamber or cold storage room until desired temperatures were reached.

The regular procedure for sustained vacuum fumigation experiments consisted of:

1. Placing a cart containing the lice and eggs previously described into a chamber.
2. Withdrawing the air until a 28.5 inch mercurial vacuum was reached.
3. Introducing a measured dosage of the gas into the chamber. This brought about a slight reduction in the vacuum depending on the amount of gas used. (The predetermined exposure period to the full concentration of the gas was timed from the instant the last of the gas entered the chamber until the vacuum was broken.)
4. Breaking the vacuum by introducing outside air.
5. Removing the gas from the clothing by three successive 25 inch "air wash" vacuums.
6. Operating the exhaust fan for 1 minute, with the breaker valve open, to draw air currents to the rear of the chamber before opening the door to remove the fumigation cart.

The seven containers were taken from the blankets, and the pieces of cloth holding the lice and eggs were transferred to numbered containers and returned to the incubator. The active stages of lice were inspected at half hour intervals to determine the kill and the eggs were checked daily for possible hatch.

The procedure for dissipated vacuum fumigation varied from the sustained vacuum fumigation in one respect: the reduction of the vacuum to 5 inches with outside air following the introduction of methyl bromide. The period of exposure was timed from the entrance of the last of the gas into the chamber until fresh air was introduced to reduce further the 5-inch vacuum to zero. The three air washes and the ventilation of the chamber followed as in the sustained vacuum fumigation.

A total of five minutes was required to withdraw the air for the initial vacuum, the three air wash vacuums and the ventilation of the chamber. The influence of outside air temperature on the liquid methyl bromide and the quantity of liquid employed, varied the time for introducing the gas from 10 seconds to more than a minute. Lice were actually subjected to the full concentration of the gas for definite periods of time as listed in the tables, but precautions necessary to eliminate all gas from the chamber required that the blankets remain in the chambers for an additional 4 minutes.

The dosages used in the experiments were 0.50, 0.75, 1.00, 1.125, 1.25 and 1.50

pounds of methyl bromide per 100 cubic feet and the time of exposure varied from 5 to 35 minutes, at 5-minute intervals. Dosage×exposure factors were therefore above and below those recommended by the Office of the Surgeon General. Four or six experiments were run simultaneously with variations in either the dosage or exposure. They were planned to produce unfavorable to favorable results by

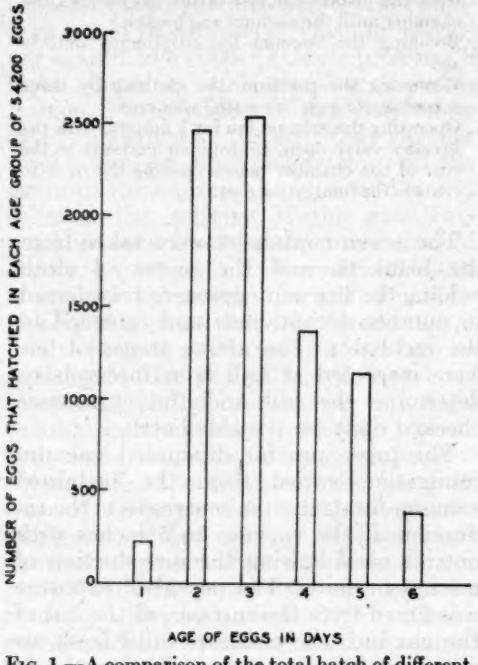

FIG. 1.—A comparison of the total hatch of different ages of body lice eggs in 271 methyl bromide vacuum fumigation experiments.

including at least one experiment in which lice survived with low dosages or short exposure periods.

DISCUSSION.—The metabolism of the lice and the activity of the gas were influenced by the temperatures of the blankets, outside air and chambers at the time of fumigation. These temperatures were recorded, included in the tables and must be considered in the rapid vacuum fumigation of clothing with methyl bromide. The blanket temperatures in these experiments were taken at the center of the 60 blankets immediately following fumigation. The experiments included combinations of chilled and incubated lice in chilled and warm blankets to duplicate the variations in temperature that would be found in clothing and equipment during all months. Only the outer layers of clothing were warmed during the fumigation procedure. The outside air temperature was an important factor during the cold winter months. The tanks containing the methyl bromide liquid were uncovered and the rapidity with which the methyl bromide entered the chambers was influenced directly by the surrounding air temperature. The outside air used in the dissipated vacuum procedure influenced the activity of the methyl bromide gas favorably during warm weather and less favorably during cold weather. The chamber temperatures were readily controlled and in the majority of the experiments were generally above 24° C. A few exceptions will be noted in experiments conducted in similar chambers at the Norfolk Army Base where higher temperatures were maintained by use of a high pressure steam heating system.

All lice are very active immediately after fumigation with methyl bromide. If the dosage and exposure have been adequate the lice will become paralyzed and will neither feed, breed nor oviposit before death. If the amount of gas or the time of exposure have been inadequate although fatal, the time elapsing between fumigation and the death of the last louse will be extended many hours by a small percentage of lice, and some will feed, breed and oviposit before death. The active stages have proven generally more resistant to the gas than the egg stage.

The percentages of hatch of each of the six age groups of eggs in each experiment were calculated and recorded, and the results showed that eggs of the same age were uniformly resistant to the gas. When six age groups of eggs were fumigated at one time there was a marked difference in their resistance. This resistance was uniform throughout the experiments. When hatch occurred in the eggs that were 2, 3, 4, and 5 days old, there was less hatch or no hatch in the 1 and 6 day old eggs. As space does not permit this detailed information, the totals of the eggs that hatched in 271 of 311 experiments are given in figure 1. All eggs in the excluded experiments hatched as a result of low dosages or insufficient exposures to the gas. If they had been included, the picture of egg resistance to the gas would

have been distorted. The figures reveal that lice eggs are least resistant to the gas when less than 24 hours old and most resistant when 2, 3, 4 and 5 days old. If the egg stage were to be used in additional experiments, only the 2, 3 and 4 day old eggs would be needed because of their high resistance to the gas. This would enable a greater number of experiments to be carried out without increasing the colony of lice. The 2, 3 and 4 day old eggs however, are less resistant under most conditions than the active stages of lice.

One hundred and forty-eight of the 311 experiments are included in tables 1, 2, 3 and 4. The excluded experiments, in which the temperature conditions varied slightly from those included in the tables substantiate the reported results. As the factors of dosage, time of exposure, temperature of the blankets, outside air and chambers varied; and as the experiments used chilled or incubated lice, as well as sustained and dissipated vacuum procedures, minute comparisons of the results within one table or between any of the four tables are difficult to make. In a few cases the chilled and incubated lice of two experiments were fumigated within the blankets of the same cart at the same time and comparable results were obtained. The variable factors in the majority of non-concurrent experiments give a fundamental working picture of rapid vacuum fumigation for temperature conditions above 24° and below 10° C.

Table 1 shows the results obtained with incubated lice in sustained and dissipated vacuum fumigation experiments with temperatures of the blankets, outside air and chambers above 24° C. to simulate summer temperatures. The lice were exposed to the full concentration of the gas for 5, 10, 15 and 20 minutes and the dosages ranged from 0.5 to 1.25 pounds of methyl bromide per 100 cubic feet. Practically no differences were shown in the results obtained with sustained and dissipated procedures at summer temperatures. Both were effective and an exposure of 15 minutes to 1 pound of methyl bromide per 100 cubic feet was adequate to kill all stages of lice within a short time. The active stages became paralyzed soon after fumigation and neither fed, bred nor oviposited before death.

Table 1.—Incubated lice fumigated with methyl bromide gas at summer temperatures in sustained (S) and dissipated (D) vacuums. (Approximately 100 nymphs and adults and 1200 eggs of six age groups.)

Vacuum	Pounds Methyl Bromide per 100 Cu. Ft.	Temperatures (°C.) Blanket	Outside Air	Chamber	Time after Fumigation Required to Produce a 100% Kill (Hours)	Percentage Surviving Fumigation	Average Hatch of Eggs
Five Minute Exposure							
S	0.50	25	23	25		7	92%
D	0.50	25	23	25		31	61
S	0.75	30	28	30	12.5		46
D	0.75	28	29	28	28		1
S	1.00	25	11	32	7		4
D	1.00	28	24	32	22		0
S	1.125	28	29	29	4		1
D	1.125	29	23	27	7		0
S	1.25	29	32	28	1		0
D	1.25	29	32	28	6		0
Ten Minute Exposure							
S	0.50	25	23	25	24		16%
D	0.50	25	23	25	27		1
S	0.75	31	28	30	3.5		1
D	0.75	28	29	29	3		0
S	1.00	25	11	33	3.25		0
D	1.00	28	24	32	5		0
S	1.125	28	29	29	2		0
D	1.125	29	23	27	1.5		0
S	1.25	29	25	28	1.25		0
D	1.25	29	32	28	2		0
Fifteen Minute Exposure							
S	0.50	25	22	29	7		17%
D	0.50	25	23	25	21		0
S	0.75	30	28	30	2		0
D	0.75	29	29	29	2		0
S	1.00	25	11	33	6		0
D	1.00	28	24	32	3		0
S	1.125	28	29	29	2		0
D	1.125	29	23	27	1.5		0
S	1.25	29	25	28	2		0
D	1.25	29	32	28	1		0
Twenty Minute Exposure							
S	0.50	23	12	28	7.75		0%
D	0.50	25	23	25	7		0
S	0.75	30	28	30	1.5		0
D	0.75	29	29	29	1		0
S	1.00	25	11	32	3		0
D	1.00	28	24	32	3		0
S	1.125	28	29	29	4.5		0
D	1.125	29	23	27	1.25		0
S	1.25	29	32	28	1.5		0
D	1.25	29	32	28	0.5		0

Table 2 shows the results obtained in sustained and dissipated vacuum fumigations with lice chilled at 6° C. for 24 hours prior to use. Temperature conditions in these experiments were encountered in the fumigation of clothing and equipment

during cold weather. The blanket temperatures were between zero and 10° C., the temperatures of the chambers between 24° and 31° C. and the temperatures of the outside air used to dissipate the vacuums were between 1° and 7° C. The dosages ranged from 0.5 pound to 1.5 pounds per 100 cubic feet and the exposures from 20 to 35 minutes, at 5-minute intervals.

Table 2.—Lice chilled at 6° C. for 24 hours prior to fumigation with methyl bromide in sustained (S) and dissipated (D) vacuums; blanket temperatures between 0° C. and 10° C. (Approximately 100 nymphs and adults and 1200 eggs in six age groups.)

Vacuum—	Pounds Methyl Bromide per 100 Cu. Ft.	Temperatures (°C)			Time after Fumigation Required to Produce a 100% Kill (Hours)	Percentage Surviving Fumigation	Average Hatch of Eggs
		Blanket	Outside Air	Chamber			
Twenty Minute Exposure							
S	0.50	9	19	25		1	9%
D	0.50	7	7	29		84	14
S	0.75	9	19	25	7.5		2
D	0.75	7	7	29		79	15
S	1.00	7	19	25		4	1
D	1.00	7	7	29		7	0
S	1.125	9	19	25	7		0
D	1.125	7	7	29		1	0
S	1.25	9	21	29		2[2]	0
D	1.25	7	7	29		12	0
S	1.50	9	19	25	6		0
D	1.50	7	7	29		2	0
Twenty-five Minute Exposure							
S	0.50	6	14	30		1	5%
D	0.50	5	6	29		89	6
S	0.76	8	14	31	8.5		0[1]
D	0.75	5	6	29		83	1
S	1.00	7	14	31		1	0
D	1.00	5	6	29		61	0
S	1.125	7	14	31	7		0
D	1.125	5	6	29		52	0
S	1.25	2	2	34		1	0
D	1.25	5	6	29		1	0
S	1.50	7	14	30		1[2]	0
D	1.50	5	6	29	70		0
Thirty Minute Exposure							
S	0.50	6	5	30		6	37%
D	0.50	4	1	28		66	3
S	0.75	6	5	30	48		1[2]
D	0.75	4	1	27		1	0
S	1.00	7	5	28	10.5		0
D	1.00	5	1	28		1	0
S	1.125	7	5	27	5		0
D	1.125	5	1	28		1	0
S	1.25	8	19	27		1[2]	[3]
D	1.25	4	1	26	12.25		0
S	1.50	8	5	24	5		0
D	1.50	4	1	26	13.5		0

Table 2.—(*Continued*)

Vacuum—	Pounds Methyl Bromide per 100 Cu. Ft.	Temperatures (°C)			Time after Fumigation Required to Produce a 100% Kill (Hours)	Percentage Surviving Fumigation	Average Hatch of Eggs
		Blanket	Outside Air	Chamber			
Thirty-five Minute Exposure							
S	0.50	1	0	24		7	31%
D	0.50	8	4	29		55	1[1]
S	0.75	9	12	28	5.25		0
D	0.75	8	4	28		1	0
S	1.00	9	12	28	7.25		
D	1.00	6	4	28	27.5		0[3]
S	1.125	0	0	25	5.5		0
D	1.125	8	4	28	3.5		0
S	1.25	0	0	25	5.5		0
D	1.25	7	4	28	5.5		0
S	1.50	0	0	24	4.5		0
D	1.50	8	4	28	3.5		0

[1] Less than 1% hatched.
[2] Surviving lice molted after fumigation.
[3] No eggs used in experiment.

When a comparison is made in this table between the sustained and dissipated procedures, the dissipated vacuum fumigation is found to be less effective in the shorter exposure periods and with the lower dosages. The cooling of the methyl bromide gas by the dissipation of the vacuum with cold air lessens the activity of the gas. However, the more natural environment created for the lice with the dissipated vacuum partially compensates for the cooling of the gas. The experiments reveal that in either the sustained or dissipated procedure, when the clothing has been chilled below 10° C., the time of exposure must be extended to at least 35 minutes and the dosage increased to 1.5 pounds of methyl bromide per 100 cubic feet.

It will also be noted in table 2 that in many experiments a small percentage of nymphs in the process of molting were not killed by the gas. In other experiments, a few lice in the process of molting may have brought about a prolongation of the period between fumigation and death of the last louse when the majority of the lice died in a shorter period of time.

Table 3 shows the results obtained with incubated lice in sustained and dissipated vacuum fumigation experiments in which

temperatures of the blankets were between zero and 10° C. The temperature conditions in these experiments were seldom encountered in the fumigation of clothing but such experiments were carried out to obtain a comparison with chilled lice fumigated under similar conditions as presented in table 2. The temperatures of the chambers were between 24° and 31° C., and the temperatures of the outside air used to dissipate the vacuums between zero and 7° C. The dosages ranged from 0.5 to 1.5 pounds per 100 cubic feet and the exposures from 20 to 35 minutes at 5 minute intervals.

Table 3.—Incubated lice fumigated with methyl bromide gas in sustained (S) and dissipated (D) vacuums; blanket temperatures between 0° and 10° C. (Approximately 100 nymphs and adults and 1200 eggs in six age groups.)

Vacuum—	Pounds Methyl Bromide per 100 Cu. Ft.	Temperatures (°C)			Time after Fumigation Required to Produce a 100% Kill (Hours)	Percentage Surviving Fumigation	Average Hatch of Eggs
		Blanket	Outside Air	Chamber			
Twenty Minute Exposure							
S	0.50	9	19	25	23		5%
D	0.50	7	7	29		72	16
S	0.75	9	19	25	9		4
D	0.75	7	7	29		66	2
S	1.125	9	19	25	9		0
D	1.125	7	2	26		10	0
S	1.50	9	19	25	7		0
D	1.50	7	7	29	13		0
Twenty-five Minute Exposure							
S	0.50	6	14	30	25.5		2%
D	0.50	5	6	29		56	[1]
S	0.75	8	14	31	8.5		0
D	0.75	5	6	29		6	[1]
S	1.00	7	14	31	10.5		0
D	1.00	5	6	29	44		[1]
S	1.25	7	14	31	4		0
D	1.25	5	6	29	12.5		[1]
S	1.50	10	21	29	4		0
D	1.50	5	6	29	8		0
Thirty Minute Exposure							
S	0.50	6	5	30		1	[1]
D	0.50	4	1	28		22	[1]
S	0.75	6	5	30	13		[1]
D	0.75	4	1	27	11		[1]
S	1.00	7	5	28	13		[1]
D	1.00	5	1	28	12		[1]
S	1.25	7	5	27	5		[1]
D	1.25	4	1	26	10		[1]
S	1.50	8	5	24	5		0
D	1.50	4	1	26	11		0
Thirty-five Minute Exposure							
S	0.50	1	0	24		50	9%
D	0.50	6	12	32		1	0
S	0.75	0	0	24		2	0
D	0.75	6	0	24	27		0
S	1.00	0	0	24		1	0
D	1.00	6	0	24	17		0
S	1.125	0	0	25	10		0
D	1.125	6	0	25	9		0
S	1.25	0	0	24	10		0
D	1.25	6	0	24	8		0
S	1.50	0	0	24	10		0
D	1.50	6	0	24	8		0

[1] No eggs used in experiment.

Table 4.—Incubated lice fumigated with methyl bromide in sustained vacuum fumigation; chamber temperatures ranging from 25° C. to 64° C. Dosage 0.5 pound per 100 cubic feet. (Approximately 100 nymphs and adults and 1200 eggs in six age groups.)

Temperatures (°C.)			Hours after Fumigation Required to Produce a 100% Kill	Percentage Surviving Fumigation	Average Percentage Hatch of Eggs
Blanket	Outside Air	Chamber			
Ten Minute Exposure					
25	23	25	24		16
26	22	30	21		11
27	26	46	23		8
28	26	52	2		0
28	28	56	2.5		0[1]
27	26	60	3.5		1
28	32	60	2		0
Fifteen Minute Exposure					
25	23	25		1	32
25	22	29	7		17
26	26	41	4		2
27	26	52	[2]		0
28	28	54	—	[3]	0
27	26	62	[2]		0
28	32	64	7		0
Twenty Minute Exposure					
23	12	28	7.75		0
26	26	45	1.25		0
28	28	54	4		0
28	26	54	0.75		0
27	26	57	2.5		0
29	32	59	[2]		0

[1] Less than 1% hatched.
[2] Surviving lice molted after fumigation.
[3] 99% dead within two hours.

At low dosages and with short exposure periods the dissipated procedure was generally less effective than the sustained procedure. It will be noted that this was also true when chilled lice were used in similar experiments as shown in table 2. All eggs were killed in the sustained and dissipated procedures with longer exposure periods and higher dosages, and there was little difference in either procedure in the length of time between fumigation and death of the last louse.

Whenever incubated lice are found in chilled clothing, usually some lice are present which have been chilled for many hours. Consequently the same dosage ×exposure factors deduced from table 2

are recommended, namely, an exposure of at least 35 minutes to 1.5 pounds of methyl bromide per 100 cubic feet.

High chamber temperatures were used in several sustained vacuum fumigation experiments as shown in table 4. These experiments were carried out at the Norfolk Army Base in chambers of design and construction similar to those at Newport News but with a high pressure steam heating system. They were conducted after the other experiments had been completed to determine the effectiveness of high chamber temperatures. The chamber temperatures varied from 25° to 64° C. The dosage of 0.5 pound of methyl bromide per 100 cubic feet was used in all experiments. The temperatures of the blankets and the outside air were generally between 23° and 32° C. The periods of exposure were 10, 15 and 20 minutes. Temperatures taken at the center of the blankets before and after fumigation revealed that the chamber heat did not penetrate to the center of the pile where the lice were located.

These experiments indicate that the activity of the gas is greatly increased by the higher chamber temperatures and a greater kill of the eggs, and a quicker kill of the active stages of lice result. Although the dosage in these experiments was low, the table reveals that if high chamber temperatures could be maintained by use of a high pressure steam heating system, the dosage might be materially reduced in rapid vacuum fumigation.

Table 4 also shows that at low dosages and with short exposures, the period of time elapsing between fumigation and the death of the last louse is inconsistent, because lice in the process of molting may extend this period by several hours, or even survive.

SUMMARY.—Sustained or dissipated vacuum fumigation with methyl bromide gas at the rate of 1 pound per 100 cubic feet for 15 minutes at temperatures above 24° C. produce a complete kill of all stages of body lice. This was a reduction of 15 minutes in the time recommended by the Office of the Surgeon General for atmospheric fumigation.

When clothing temperatures were between zero and 10° C. the sustained and dissipated procedures were effective with exposures of at least 35 minutes and dosages of 1.5 pounds per 100 cubic feet. The sustained procedure is recommended at these temperatures as more reliable because with lower dosages and shorter exposures the dissipated procedure was less effective.

It was noted that nymphs in the process of molting were more resistant to the gas when the lice were chilled prior to fumigation.

Eggs were invariably killed by lower dosages and shorter exposure than the active stages in either dissipated or sustained fumigation. The 2, 3, 4 and 5 day old eggs were more resistant than the 1 and 6 day old eggs.—5-2-46.

COTTON STATES BRANCH TO MEET IN BILOXI, MISSISSIPPI

The annual meetings of the Cotton States Branch of the Association will be held in Biloxi, Mississippi, on January 15, 16, and 17, 1947. Headquarters will be at the Buena Vista Hotel in Biloxi.

The Branch has extended a special invitation to members of industry and entomologists from other branches of the Association, to attend these meetings and those fortunate enough to be able to take a winter vacation on the Gulf Coast should find the meetings not the least of the attractions offered by such a trip.

The Chairman for the meetings will be Mr. R C. Gaines, Vice-Chairman Mr. J. A. Berley while the efficient Secretary, Dr. John T. Creighton will, as usual, control the steering gear.

Toxicity and Repellency of Certain Organic Compounds to Larvae of *Lucilia sericata*[1,2]

ERWIN S. LOEFFLER and W. M. HOSKINS

During a systematic study of repellent materials to protect animals from adult flesh flies, investigation was undertaken of toxic or repellent action of these materials toward larvae of *Lucilia sericata* (Meigen). Not only would larvicidal action reinforce the prophylactic value of fly repellents, but it would allow complete treatment of a fly-invaded wound by one application. A rapid preliminary test for evaluating the unusual toxicity and repellence requirements of a larval repellent was needed. A suitable quick screening test was developed and used to evaluate several series of organic compounds including dichloro diphenyl trichloroethane (DDT) and hexachlorocyclohexane.

To test larvicides several interesting laboratory methods have been used. Hobson (1937) absorbed a nutrient solution of 7 per cent Loeffler's dried serum and 1 per cent *Marmite* plus toxicant on a pad of cotton wool and let larvae feed on them. Hoskins *et al.* (1941) incorporated toxicants into a synthetic diet of casein, yeast, and butter, in agar solution, and determined the lowest concentration of toxicant necessary to cause complete mortality of flesh fly larvae. McCulloch (1940) incorporated toxicants into ground meat, cultured larvae on the meat in calico covered containers for 24 hours, then uncovered the containers and placed them in sand-filled breeding jars and noted inhibition of pupation. Dead larvae were counted at intervals to determine speed of kill. Lennox (1940) in an excellent examination of toxicants to blow fly larvae, cultured them on a medium composed of yeast, sodium chloride, and agar or egg white to which the toxicant was added. Toxicity was measured by growth retardation and rate of mortality. Relation of contact time to kill was also determined by removing larvae at known intervals from a poison media to a poison-free media.

In the foregoing methods little quantitative evidence is available as to the repellency of the toxicants, although Hoskins *et al.* differentiated between starvation toxicity due to repellency of the food and toxicity from contact or stomach poisoning. Lennox, too, noted larvae wandering or crawling away from media to the walls of the culture bottle, especially when higher concentrations of toxicants were incorporated into the media.

The toxic and repellent properties of a larvicide for myiasis treatment have a unique relationship. For most insect control, an immediate toxic action of a contact poison is desired; however, because of the nature of a myiotic invasion, this immediate kill may be objectionable since it necessities the removal of dead maggots from wound sinuses after treatment. This is usually a difficult hand operation that aggravates the wound and increases the possibility of restrike, but it is necessary to avoid septic effects from dead maggots. This is unavoidable when a rapid acting material such as benzene is used as a larvicide. An ideal myiotic wound treatment would both kill maggots and cleanse them from the wound, thus speeding wound granulation and removing a cause of restrike. Such a larvicide would have a delayed but positive toxicity and a strong larval repellency; toxic action would thus be delayed sufficiently to allow maggots to be repelled from the wound to the surrounding wool and yet die before restrike could occur. To the 10 criteria for a good wound dressing given by Lennox (1941) may be added the property of driving larvae from the wound. Dead larvae well scattered in the wool would soon dry up and fall off without presenting a danger to the animal. The commonly used toxicity or repellency tests may not evaluate a material according to these criteria. Rather, a test combining delayed toxicity and repellency and simulating the special conditions met in a myiotic wound would be required.

In addition, to be effective a material must first penetrate down into the wound and contact the larvae; thus a suitable larvicidal repellent must penetrate both

[1] Contribution from the laboratory of insect physiology and toxicology, Division of Entomology and Parasitology, University of California.

[2] First paper in a series on "The Insecticidal Effects of Organic Compounds."

the oily and aqueous phases present in a myiotic wound. Wool has a yolk which is primarily an ether-soluble fraction derived from the sebaceous glands and a water-soluble "suint" derived from the sweat glands. Long wool is advantageously removed from around bad wounds (Knipling 1942) but the remaining wool is often thoroughly wetted by the aqueous exudate from the suppurating wound. Penetration, repellency, and delayed toxicity are the chief factors in the choice of a wound prophylactic.

The development of a laboratory test to evaluate these factors required rather extensive experimentation but a simple test method was evolved. Since the myiotic wound is essentially a larval culture thoroughly impregnating the immediate surrounding area with blood, fluids, and excrement, a situation simulating an infested wound was obtained by allowing larvae to form sinuses in an agar medium covered by raw wool. After treatment with toxicants, the agar cultures were placed in close proximity to unsprayed agar food cultures so that larvae could migrate at will, similar to the situation in a wound. The mechanical details of the test method are briefly described in the next paragraph.

EXPERIMENTAL PROCEDURES.—Fifteen second-instar maggots from a stock colony reared on fish heads were placed in small stender dishes containing 20 cc. of an artificial food of casein, yeast, agar, and butter (Hoskins *et al.* 1941) covered with a pad of raw wool which was pressed down closely. The dishes were then covered with glass lids and placed in a constant temperature cabinet (25° C., R.H. 50 per cent) for 24 hours to allow the maggots to become established in the food. The larvae started eating on and into the agar medium in a short time, making typical sinuses and impregnating the surrounding wool with their exudate. The loose lids allowed considerable ventilation but prevented any appreciable drying of the medium.

After 24 hours the stender dishes were taken from the cabinet, their glass lids removed and the contents sprayed with 5 cc. of a solution of the desired toxicant from a precision sprayer. The sprayer and dish holder were rigidly mounted within a draft-free glass cabinet and checked for accurate delivery of spray at frequent intervals. Each uncovered dish was placed immediately in a wide mouth pint mason jar containing unsprayed agar food medium; the jar was closed with a screw-on wire mesh top and put back into the constant temperature cabinet. The larvae were all in the third instar at this time. At 2 and 12 hour intervals the jars were inspected for toxicity and repellency to larvae. Since the larvae were not taken out for close examination at the 2 hour interval, the figures for mortality are only approximate and sometimes slightly inconsistent with those gotten by careful examination at the 12 hour interval. The tests were evaluated on the following bases:

(1) The larvae leaving the sprayed stender dishes for the surrounding mason jar gave a measure of the repellency of the spray, except in cases of immediate toxic effect (Tables 1, 2 and 3.

(2) The larvae dying in the stender dishes within the 2 hour period (Tables 1, 2 and 3, column 4) gave a measure of rapid mortality which would largely prevent escape of the larvae even if they were repelled. Those dying within the 12 hour period (Tables 1, 2 and 3, column 7) included in addition those larvae which died more slowly and, in cases shown in tables 2 and 3, were prevented from migrating by the onset of toxic effects, since the solvent *Cellosolve* tended to repel them.

(3) The number of larvae dead in the unsprayed mason jars indicated a delayed mortality that occurred only after they were repelled from the stender dishes (Tables 1, 2 and 3, columns 5 and 8).

In all cases the unsprayed control larvae run simultaneously exhibited no repellency and negligible mortality and would migrate from the favorable food source only to pupate, which occurred 3 to 4 days hence. Five trials were run on each material with an equal number of controls, and values given are the average of all trials. A standard comparison spray, 5 per cent *Lethane 384*, was used occasionally to check constancy of reaction of the larvae.

RESULTS.—If the assumption is valid that the criteria for a good larvicide are repellency plus delayed mortality, then an ideal additive property for an adult fly repellent would be to repel completely

and then kill all the maggots. Thus the repellency plus delayed mortality gives, for the purposes of comparison, a numerical rating of the effectiveness of the larvicides. Similarly, rapid mortality plus the delayed mortality gives the orthodox measure of total toxicity, although exposure time to the toxicants depends upon how soon the larvae migrated. In order not to underestimate the effects of the more slowly-acting chemicals, it is preferable to use the results obtained at the 12 hour inspection though, with a few exceptions, these differ but little from the results at 2 hours.

Others, such as *Lethnae 384*, dichloro diphenyl trichloroethane (DDT), and hexachlorocyclohexane, are well known toxicants. The sprays usually contained 5 per cent by volume of the liquid chemicals in *Cellosolve*. The solids were used at the rate of 5 grams per 100 cc. total volume. Since the *Cellosolve* imparts an initially high repellency to the spray (Table 1), any decrease in repellency after the addition of the test materials should be due to a rapid toxic action which prevented migration. Five per cent may not have been the optimum concentration for all materials, but it allowed a relative basis of comparison which should serve to screen out promising materials. Spray A is included in the materials tested to obtain practical information on its repellent and toxic effect on larvae. This spray, composed of 50 per cent by volume *Plastol*, 20 per cent by volume carbitol acetate, and 30 per cent by volume dimethallyl disulfide, was found to be an excellent adult fly repellent to ovipositing *Lucilia sericata* in laboratory experiments and field trials on sheep.[1]

Table 1.—Repellency and mortality resulting from spraying third instar larvae of *Lucilia sericata*.

Compounds (1)	(2)	2 Hours After Spraying (3)	(4)	(5)	12 Hours After Spraying (6)	(7)	(8)
			Mortality (per cent)			Mortality (per cent)	
Name and formula	Concentration in volume (per cent)	Repellency (per cent)	Inside sprayed area	Outside sprayed area	Repellency (per cent)	Inside sprayed area	Outside sprayed area
Alcohols and Acetates							
butyl alcohol C_4H_9OH	100	15	79	3	15	85	3
butyl acetate $C_4H_9COOCH_3$	100	12	86	1	12	87	7
Cellosolve[1] $C_2H_5OCH_2CH_2OH$	100	75	0	1	97	1	5
Cellosolve acetate $CH_3COOCH_2CH_2OC_2H_5$	100	40	53	5	40	62	22
Cellosolve acetate	5	90	4	6	90	10	7
kerosene	95						
butyl *Cellosolve* $C_4H_9OCH_2CH_2OH$	100	33	60	11	32	71	12
butyl *Carbitol*[2] $C_4H_9OCH_2CH_2OCH_2CH_2OH$	100	60	39	31	60	41	28
butyl *Carbitol* acetate $CH_3COOCH_2CH_2OCH_2CH_2OC_4N_9$	100	31	60	22	34	66	22
butyl *Carbitol* acetate	75	37	37	19	51	46	23
water	25						
phenyl *Carbitol* $C_6H_5OCH_2CH_2OCH_2CH_2OH$	100	22	57	9	30	68	9
phenyl *Cellulosolve*	33	34	56	16	41	56	17
	57						
Petroleum fractions							
kerosene	100	64	10	9	71	41	1
Oil No. 1[3]	100	0	0	0	10	3	5
Oil No. 2[4]	100	30	1	0	0	36	1

[1] *Cellosolve* is the trade name of ethylene glycol monoethyl ether, $C_2H_5OCH_2CH_2OH$.
[2] *Carbitol* is the trade name of diethylene glycol monoethyl ether, $C_2H_5OCH_2CH_2OCH_2CH_2OH$
[3] Oil No. 1: Petroleum oil, viscosity SSU @ 100°F = 46, unsulfonatable residue 87%.
[4] Oil No. 2: Petroleum oil, viscosity SSU @ 100°F = 50, unsulfonatable residue 70%.

The first group of materials tested (Table 1) were potential carriers, *i.e.*, suitable vehicles for carrying toxicants and repellents into the wound. The toxic and repellent action of many of the materials would make them a functional part of the spray.

TOXICITY AND REPELLENCY TO 3RD INSTAR LARVAE.—A total of 38 materials, the majority containing sulfur in an organic molecule, were examined (Table 2). Many of these had been tested previously as repellents for adult blowflies.

[1] Unpublished work, Loeffler & Hoskins, 1939–41.

Table 2.—Repellency and mortality of third instar *Lucilia sericata* larvae resulting from spraying with a repellent spray (*Cellosolve*) plus added toxicants.

Compounds (1)	(2)	2 Hours After Spraying (3)	(4)	(5)	12 Hours After Spraying (6)	(7)	(8)
			Mortality (per cent)			Mortality (per cent)	
Name and formula	Concentration in volume (per cent)	Repellency (per cent)	Inside sprayed area	Outside sprayed area	Repellency (per cent)	Inside sprayed area	Outside sprayed area
Thiocyanates							
butyl thiocyanate C_4H_9SCN	5	23	62	12	27	73	23
methallyl thiocyanate $CH_2{:}C(CH_3)CH_2SCN$	5	77	15	29	85	15	34
butyl ammonium thiocyanate $C_4H_9NH_2SCN$	5	60	23	4	65	29	6
Lethane 384 (50 per cent butyl *Carbitol* thiocyanate) $C_4H_9OCH_2CH_2OCH_2CH_2SCN$	5	33	—	12	33	71	13
Lethane 384	10	—	—	—	12	88	12
Lethane 384 special[1]	10	51	48	35	51	48	35
Monosulfides							
ethyl acetyl sulfide $C_2H_5SCOCH_3$	5	82	7	0	82	10	7
isobutyl acetyl sulfide $(CH_3)_2CHCH_2SCOCH_3$	5	59	17	0	69	22	1
tertiary butyl acetyl sulfide $(CH_3)_3CSCOCH_3$	5	40	12	3	75	25	7
tertiary butyl acetyl sulfide	5	56	36	8	48	47	5
kerosene	95						
methallyl sulfide $CH_2{:}C(CH_3)CH_2SCH_2(CH_3)C{:}CH_2$	5	82	4	6	82	21	4
kerosene	95						
ethyl benzyl sulfide $CH_3CH_2SCH_2C_6H_5$	2	90	12	21	100	0	21
ethyl benzyl sulfide	5	68	29	3	70	29	7
phenoxathiin $OC_6H_4SC_6H_4$	5	35	57	22	36	64	29
ethylene glycol ethyl thioether $C_2H_5SCH_2CH_2OH$	5	28	17	3	64	36	10
thiodiglycol $HOCH_2CH_2SCH_2CH_2OH$	5	66	17	2	79	19	3
diethylene monothiodioxide $OCH_2CH_2SCH_2CH_2$	5	77	8	0	82	17	8
Disulfides							
n-butyl disulfide $CH_3(CH_2)_3SS(CH_2)_3CH_3$	2	78	3	5	100	0	5
n-butyl disulfide	5	57	0	0	94	1	0
methallyl disulfide $CH_2{:}C(CH_3)_2SSCH_2(CH_3)C{:}CH_2$	5	6	13	3	70	34	5
kerosene	95						
Nitrogen compounds							
acetbromamide $CH_3CONHBr$	5[2]	96	4	0	92	6	4
p-nitroaniline $NO_2C_6H_4NH_2$	5[2]	51	4	3	70	24	11
diphenylamine $C_6H_5NHC_6H_5$	5[2]	90	7	19	84	16	63
phenothiazine $NHC_6H_4SC_6H_4$	5[2]	8	93	5	8	91	7
phenothiazine	2[2]	50	35	16	59	39	20
butyl *Carbitol* acetate	98						
m-dinitrobenzene $NO_2C_6H_4NO_2$	5[2]	27	62	10	27	72	14
m-dinitrobenzene	2[2]	43	25	12	60	37	15
butyl *Carbitol* acetate	98						
mono *n*-butyl thiourea $C_4H_9NHCSCNH_2$	5[2]	23	4	0	64	17	6
Halogenated compounds							
carbon tetrachloride CCl_4	100	0	100	0	0	100	0
butyl *Carbitol* chloracetate $C_4H_9OCH_2CH_2OCH_2CH_2OOCCH_2Cl$	5	69	23	27	71	28	0
butyl *Cellosolve* chloroacetate $C_4H_9OCH_2CH_2OOCCH_2Cl$	5	59	34	25	58	42	58
tetra ethylene glycol dichloride $ClCH_2CH_2OCH_2CH_2OCH_2H_2OCH_2CH_2Cl$	5	31	0	0	65	9	6
epichlorohydrin OCH_2CHCH_2Cl	5	53	5	2	69	31	67

[1] *Lethane 384 Special:* 50% of a mixture of butyl carbitol thiocyanate and β-thiocyano esters of higher fatty acids dissolved in kerosene.

[2] In weight/volume per cent.

Table 2.—(*Continued*)

Compounds (1)	(2)	2 Hours After Spraying (3)	(4)	(5)	12 Hours After Spraying (6)	(7)	(8)
			Mortality (per cent)			Mortality (per cent)	
Name and formula	Concentration in volume (per cent)	Repellency (per cent)	Inside sprayed area	Outside sprayed area	Repellency (per cent)	Inside sprayed area	Outside sprayed area
dichloroethyl phthalate $C_6H_4(COOC_2H_4Cl)_2$	5	57	7	1	84	13	9
DDT[3] dichloro diphenyl trichloroethane $(C_6H_4Cl)_2CHCCl_3$	5[2]	36	—	2	36	64	36
Benzene hexachloride[4] (γ-hexachlorocyclohexane) $C_6H_6Cl_6$	5[2]	0	100	0	0	100	0
Benzene hexachloride	1[2]	14	45	14	14	86	14
Benzene hexachloride	0.1[2]	—	—	—	3	97	3
Miscellaneous							
methyl isobutyl ketone $CH_3COC_4H_9$	5	60	29	0	54	43	0
methyl ethyl thioketone $CH_3CSC_2H_5$	5	33	6	0	83	6	0
tartar emetic $KSbC_4H_4O_6 \cdot H_2O$	5[2]	0	0	0	6	4	3
water	100						
tannic acid $C_{76}H_{52}O_{46}$	5[2]	3	0	0	18	0	0
water	100						
benzene C_6H_6	100	0	100	0	0	100	0
benzene	10	25	6	2	75	12	9
butyl *Carbitol* acetate	90						
O-ethyl, S-methallyl xanthate $SC(OC_2H_5)SCH_2C(:CH_2)CH_3$	5	80	12	3	75	23	16
Spray A[5]	100	—	—	—	16	85	5
carbitol acetate	20						
Plastol[6]	50						
methallyl disulfide	30						
Spray A	5	—	—	—	63	31	10

[3] Technical grade of DDT, setting point 91°C.
[4] Recrystallized gamma isomer of 1, 2, 3, 4, 5, 6-hexachlorocyclohexane.
[5] Spray A: A very effective adult blowfly repellent, as proven by field trials. Unpublished work, Loeffler & Hoskins 1939–1940.
[6] *Plastol* is the trade name of an adjuvant for effecting the properties of spray oils and is a polymerized butylene.

TOXICITY AND REPELLENCY TO 4TH INSTAR LARVAE.—Toxicity and repellency to 4th instar larvae are of lesser importance since these larvae are approaching the non-feeding stage and soon leave the wound to pupate. However, a few experiments on 4th instar larvae were tried and the results are summarized in table 3. The decreased repellency without the compensating increased rapid mortality invariably found in 3rd instar larvae, indicates that 4th instar larvae are not completely repelled by *Cellosolve*. Repellency is not as clearly defined in the 4th instar tests since migration often occurs in the unsprayed control jars as the larvae approach the prepupal stage. Since it is impossible to distinguish between these two behaviors, they have been combined under the heading "Repellency" in table 3, columns 3 and 6. In general the latter instar is more resistant to the action of the toxicants.

PENETRATION EXPERIMENTS.—Penetration into the cuticle of an insect plays a major part in the contact action of an insecticide. However, it is recognized that penetration to the maggot through wool and wound area must precede this integument contact. McGovran (1938) and Knipling (1942) greatly increased larvicidal action by the addition to toxicants of a wetting agent such as sulfonated castor oil. Since this latter penetration is important in the treatment of a myiotic wound, a simple test has been used to evaluate some of the typical carrier materials. This test is similar to standard wetting tests used widely in the textile industry (Draves 1939) except that the sample is allowed to sink under its own weight instead of being pulled under by an anchor.

The time necessary for complete submergence of a uniform piece of raw wool staple (freshly sheared) in a cylinder of the test liquid gives an approximation of the speed of penetration and wetting of wool. Since the wound, even when sheared, is often surrounded by wool saturated by the aqueous exudate from the wound, the tests were repeated using a uniformly

water-wetted wool sample. Results are given in table 4. Times indicated are the numerical average of several trials; however, the tests were found to be easily reproducible and deviations were slight.

DISCUSSION.—In considering the results on mortality, notice must be taken of the unusual conditions of exposure in these tests. Since most of the compounds were contained in a repellent diluent, *Cellosolve*, and larvae could leave the zone of spray readily and quickly, the time of cleansing of maggots from the wound is desirable. This overlooks any toxicity after the 4th instar. In a large number of cases of treated 2nd instar larvae, toxicity does occur in the prepupal or pupal stages (Hoskins *et al.* 1941). It is well known that some toxicants, especially DDT, show a slow toxic action.

If the results are interpreted in terms of the practical control of fly wounds, the complete cleansing of wounds and killing of larvae could be obtained only by a ma-

Table 3.—Repellency and mortality of fourth instar *Lucilia sericata* larvae resulting from spraying with a repellent spray (*Cellosolve*) plus added toxicants.

Compounds (1)	(2)	2 Hours After Spraying (3)	(4)	(5)	12 Hours After Spraying (6)	(7)	(8)
			Mortality (per cent)			Mortality (per cent)	
Name and formula	Concentration in volume (per cent)	Repellency (per cent)	Inside sprayed area	Outside sprayed area	Repellency (per cent)	Inside sprayed area	Outside sprayed area
Cellosolve $C_2H_5OCH_2CH_2OH$	100	37	1	0	80	8	1
thiourea NH_2CSNH_2	5[1]	23	2	2	85	2	3
thioacetamide CH_3CSNH_2	5[1]	40	2	0	60	2	0
thioacetanilide $C_6H_5NHCSCH_3$	5[1]	28	1	0	74	5	1
morpholine $OCH_2CH_2NHCH_2CH_2$	5	18	0	2	33	2	3
Dichlorethyl phthalate $C_6H_4(COOC_2H_4Cl)_2$	5	35	3	3	49	5	11
Lethane 384	5	86	—	—	87	1	35
(50% butyl Carbitol thiocyanate) $C_4H_9OCH_2CH_2OCH_2CH_2SCN$	10	69	—	0	6.9	1	57
DDT dichloro diphenyl trichloroethane $(C_6H_4Cl)_2CHCCl_3$	5[1]	15	—	0	19	81	5
DDT	1[1]	61	—	0	46	46	12
Benzene hexachloride (γ-hexachlorocyclohexane) $C_6H_6Cl_6$	0 1[1]	7	—	—	1	99	0

[1] In weight/volume per cent.

contact between spray and mobile larvae was very short in some cases. This probably limited toxicity to contact action. Any unusual method of ingestion as by the cleansing of body parts due to an irritant, as suggested by many investigators for other insects, is probably lacking with fly larvae. Most of the materials tried (with the exception of benzene and other volatile solvents) have relatively high boiling points so respiratory action is at a minimum. Similarly, structural changes of the chemicals by contact with the agar media which changes pH with maggot infestation (Michelbacher *et al.* 1932) is of relatively little importance here. Lastly, the criterion of pharmacological action was established at 2 and 12 hours after spraying, since a rapid

terial having a 100 per cent repellency and a 100 per cent delayed toxicity. None of the materials examined approximate the 200 per cent total required for an ideal material. Among the toxicants (all at 5 per cent concentration) diphenylamine has the highest total, 147 per cent, and butyl carbitol chloroacetate with 141 per cent, epichlorohydrin with 136 per cent, and methallyl thiocyanate with 128 per cent are all highly effective against the third instar larvae. Of the few materials tested on 4th instar larvae (Table 3), *Lethane 384* at 10 per cent concentration was most effective with a total repellency plus delayed mortality of 126 per cent.

Although specific compounds were being evaluated as additives for repellent

sprays, any relationship between chemical structure and toxic action is of interest. In so far as possible, chemicals were picked in homologous series or related groups; however, many series are incomplete so toxic action-structure relationships must be suggestive rather than conclusive. A few conclusions concerning the speed and magnitude of toxic action seem justified from the results.

In the glycol and diglycol alkyl ether series, total toxicity increased on replacement of the hydroxy group in the order of alcohol, acetate, thiocyanate, and chloroacetate, the latter also having the greatest delayed toxicity. Thus in the butyl *Carbitol* series the chloroacetate compound gives about the same total mortality as the analogous thiocyanate compound *Lethane 384*, which is 50 per cent butyl *Carbitol* thiocyanate in kerosene but the chloroacetate does not give the rapid mortality that characterizes the thiocyanate.

Replacement of the ethoxy group in *Cellosolve* by a butoxy group increases the toxicity, and the replacement of the butoxy by a phenoxy group may have increased toxicity slightly. The replacement of the ethoxy oxygen by sulfur in Cellosolve to give ethylene glycol ethyl thioether increases the toxicity. This increased toxicity on replacement of oxygen by sulfur has been observed previously with the carbonyl oxygen and to a lesser extent with the phenolic oxygen.

Unfortunately, none of the aliphatic sulfides or disulfides which are repellent to the adults are very toxic to the larvae at 5 per cent concentrations. The replacement of an alkyl group by a phenyl group as in ethyl benzyl sulfide did not increase toxicity. This is in agreement with Hoskins *et al.* (1941) who found that the monosulfides and to a lesser extent, the disulfides were of low toxicity and that the substitution of an aryl for an alkyl radical usually decreased toxicity. Similar decreases in repellency and toxicity against codling moth larvae were noted when alkyl radicals were replaced by aryl radicals by McAllister (1930). The addition of an acetyl group as in the alkyl sulfides or dehydrogenation of the alkyl radical as in the methallyl sulfides did not increase toxicity of the sulfides.

Thiodiphenylamine (phenothiazine), a cyclic sulfur compound, has a rapid toxicity, greater than that of any of the structurally related compounds. Thiodiphenylamine alone and in combination has been widely recommended for myiasis treatment (Parish & Knipling 1935) and many workers have found that any attempt to modify its structure decreased its toxicity (Lennox 1940) (Guy 1937); however, Parish & Knipling found that diphenylene oxide and phenothioxiin were nearly as effective as phenothiazine and possessed more favorable physical properties. In the present work the diphenylamine nucleus alone gave a much higher delayed mortality although the total mortality is slightly less than that from the thio compound. Phenoxathiin, in which sulfur is replaced by oxygen, approaches very nearly the toxicity of phenothiazine.

Table 4.—Rates of penetration of solvents through dry and wet wool.

Solvents	Time to Sink in Seconds	
	Dry Wool	Wet Wool
Cellosolve	1	1½
Butyl Carbitol	3	2
Oil #1[1]	10	17
Oil #1 plus 1% SS3[2]	10	8
Oil #1 plus 5% SS3	9	9
Oil #1 plus 5% SS3 plus 45% water	10	25
Spray A[3]	5	5
Water	120	4

[1] Oil #1: petroleum oil, viscosity SSU@100°F=51; U.R. =99%.
[2] SS3: a commercial emulsifying agent containing sodium oleyl sulfate.
[3] See table 2 for composition.

The high toxicity of some of the alkyl and alkoxy thiocyanates is well known. Butyl thiocyanate has a high toxicity but replacement of the butyl by the unsaturated methallyl grouping greatly decreases both speed of action and total toxicity. The introduction of an ammonium group to the butyl compound further reduces toxicity. At the concentrations examined, 2.5 and 5 per cent of butyl carbitol thiocyanate (toxicant of *Lethane 384*), the material was highly toxic and possessed the quick paralytic action characteristic of the thiocyanates.

Benzene alone and in combination with wound protectors has been used as a

larvicidal treatment for maggot infested wounds (Knipling 1942) and has a strong and rapid toxic action. However, in concentrations comparable to some of the other toxicants examined in the present work, it had only a low toxicity. Many other materials in equal concentrations may be expected to surpass benzene in toxicity. This is in apparent contrast to the results of Seddon (1931) who found benzene a good larvicide in concentrations as low as 5 per cent. The substitution of nitro groups for hydrogen on the benzene ring increased its rapid toxicity, as has been noted by many other investigators.

The halogenated compounds are of interest since DDT and benzene hexachloride have been shown to possess remarkable toxicities. Various theories as to their toxic action have been suggested and will not be reviewed here. The initial mode of action of many chlorinated materials has been attributed to their dissolving action on the fatty epicuticula and consequent ease of penetration into the insect (Lennox 1940). This may account, in part, for the toxic action of carbon tetrachloride, DDT, and hexchlorocyclohexane. This compound, the gamma isomer of 1, 2, 3, 4, 5, 6-hexachlorocyclohexane, possesses a toxicity in these tests at least equal to DDT and a more rapid action. At the lowest concentration tested, 0.1 gm/100 ml, hexachlorocyclohexane still gave a 100 per cent kill. Both DDT and it should be further investigated at lower concentrations. The highest delayed killing action was possessed by two other halogenated compounds, not previously known as possessing high insecticidal action against fly larvae. These compounds, butyl *Carbitol* chloroacetate, and epichlorohydrin should be excellent solvents for the multihydroxy ester waxes that have been suggested as present in the insect epicuticula. This solvent power may be a factor in their larval toxicity, both giving approximately 100 per cent kill at a concentration of 5 per cent with 70 per cent of the larvae being repelled before mortality occurs. The butyl *Carbitol* chloroacetate which structurally is related to *Lethane 384* (butyl *Carbitol* thiocyanate) and possesses an equivalent toxicity, had a slower speed of action than the rapid-acting thiocyanate. Low concentrations of *Lethane 384* have been used directly on wounds without irritation or interference with good wound granulation,[1] but the stability of the chloroacetate in contact with wound exudate has not been determined. In an independent but parallel series of tests in which flesh fly larvae were cultured on media thoroughly impregnated with the toxicants, butyl *Cellosolve* chloroacetate was repellent and more toxic than *Lethane 384* (Hoskins *et al.* 1941). Lennox (1940) found calcium chloroacetate one of the most toxic compounds to larvae of *Lucilia cuprina*. The delayed toxicity of the butyl *Carbitol* chloroacetate may make this compound valuable for myiasis treatment.

The few oils examined had moderate unsulfonatable residues and little apparent toxicity. Kerosene had a higher toxicity and repellency which may be due to its better dissolving and penetrating action or to the nature of the hydrocarbon groups present.

Spray A differs somewhat from other materials examined in that it is not a single compound but rather a combination of materials proven by previous investigations to be an especially effective and lasting blowfly repellent on sheep. Under the conditions of this test, this material had a high rapid toxicity to the third instar larvae. Admittedly it would be more advantageous if this were a delayed toxicity; however, any larvicidal toxicity of this effective fly repellent further contributes to its value, especially in preventing strike or restrike.

SUMMARY.—A new laboratory test method for systematic evaluation of larvicides for use in treatment of myiasis has been described. It establishes, as one of the criteria of a good larvicide, the ability to first repel and then kill all the maggots in a wound. Several representative groups of potential blowfly repellents have been examined for repellent and larvicidal action by this test. Diphenylamine, butyl *Carbitol* chloroacetete and epichlorohydrin were the most effective repellent larvicides. The results also indicated that in the hydroxy alkyl ether series, toxicity increased in the order alcohol, acetate, thiocyanate and chloroacetate. None of the alkyl sulfides or di-

[1]Unpublished work, Loeffler & Hoskins, 1939–40.

sulfides were toxic. Replacement of the alkyl group by the aryl group did not increase toxicity. Thiodiphenylamine was more toxic than any related compounds and omission or replacement of the sulfur by oxygen yielded toxic compounds of interest. Several halogenated compounds had high toxicity including DDT, hexachlorocyclohexane and the lesser known epichlorohydrin and butyl *Carbitol* chloroacetate. A new blowfly repellent, *Spray A*, had considerable larvicidal action to supplement its effective fly repellent action.—2-15-46.

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USDA Grasshopper Control Expert Loaned to Argentina

Dr. J. R. Parker, leading grasshopper control expert of the U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine left New York November 13 by air for Argentina. Parker went to Argentina in response to the request of the Argentine government for an entomologist who can give technical advice on the control of a grasshopper outbreak which is now occurring over wide areas in that country.

Experimental lots of new insecticides, furnished by U. S. manufacturers, were sent by air to Argentina for Dr. Parker's use. These insecticides were tested by Parker during the recent grasshopper season in the United States. A few of these materials, including benzene hexachloride, a chlorinated camphene (Hercules 3956), and another chlorinated hydrocarbon (Velsicol 1068) have shown considerable promise in killing grasshoppers and they will be tried under Argentine conditions.

Dr. Parker has been fighting grasshoppers since 1910. He has been the leading grasshopper control researcher for the Bureau of Entomology and Plant Quarantine since 1930.

Efficiency of Carbon Tetrachloride, Ethylene Dichloride and Certain Other Fumigants in Shelled Corn[1]

CHARLES H. RICHARDSON,[2] *Iowa Agricultural Experiment Station, Ames*

In the period from 1939 to 1943, large quantities of shelled corn were stored in steel bins in the mid-western states under supervision of the U. S. Commodity Credit Corporation. The well-known ethylene dichloride-carbon tetrachloride fumigant mixture which contains 75 per cent by volume of ethylene dichloride was officially recommended in May 1940 for controlling insects in this corn. Other fumigants, however, were employed in some quantity as supplies of ethylene dichloride and carbon tetrachloride were diverted by war demands to other uses.

In steel bins, the standard ethylene dichloride-carbon tetrachloride mixture at a dosage of 5 or 6 gallons per 1000 bushels proved generally an efficient fumigant. Failures with the mixture were occasionally reported, however, even under conditions apparently suitable for its successful use.

The investigation reported here was made in an attempt to determine the cause or causes of this failure. The work was directed first to examination of the toxic efficiency in shelled corn of carbon tetrachloride, ethylene dichloride and the standard mixture of these fumigants. Later, other compounds and mixtures were tested. The investigation extended from September 1941 to January 1945.[3]

HISTORICAL REVIEW.—The earlier literature on carbon tetrachloride has been reviewed by Strand (1927). Chittenden & Popenoe (1911) showed that carbon tetrachloride was considerably less effective than carbon disulfide against several species of grain-infesting insects. Most previous comparisons of carbon tetrachloride, like this one, were made with carbon disulfide which is now recognized as one of the more toxic of the common fumigants. Nevertheless, Doane (1919) reported the successful use of carbon tetrachloride for controlling weevils *Sitophilus oryza* (L.), *S. granarius* (L.), in wheat. The fumigant was sprayed onto the grain at the rate of 2 gallons per 1000 bushels as it moved from conveyers into the bins. In tight bins, a 2- or 3-day exposure was recommended. Neifert *et al.* (1925) made trials with both carbon tetrachloride and ethylene dichloride in empty flasks under laboratory conditions against *S. oryza*, *S. granarius*, *Tribolium confusum* Duv. and *Plodia interpunctella* (Hbn.). Although their data are not suitable for critical analysis, a difference in favor of ethylene dichloride is apparent. Cotton & Roark (1927) first reported the now standard ethylene dichloride-carbon tetrachloride mixture (75 volume per cent ethylene dichloride) as a fumigant for pests of stored products; the mixture was stated to be about 5 times as toxic as carbon tetrachloride. The following year Roark & Cotton (1928) recorded dosages of 638 and 226 milligrams per liter of carbon tetrachloride and ethylene dichloride respectively for complete kills of *S. oryza* within 200-gram lots of wheat in 500 cc. flasks. The exposure was 24 hours at 21 to 27° C. Shepard & Lindgren (1934) determined the 50 per cent dose (LD50) and 100 per cent dose (LD100) of carbon tetrachloride and ethylene dichloride in empty space at 5- and 24-hour exposures and temperature of 25°. for *S. oryza* and *T. confusum*. The ratios of the doses obtained from this study indicate a 3.1 to 5.8-fold greater toxicity for ethylene dichloride. Figures reported later for *T. confusum* at 30° C. and 5-hour exposure (Shepard *et al.*, 1937) show a 3.2 to 8.6-fold greater toxicity for ethylene dichloride at the higher temperature. Gunderson (1940) compared carbon tetrachloride with carbon disulfide and with several other compounds for toxicity in empty space to *T. confusum* at a 2-hour exposure and temperature of 30° C. His values for LD50 and LD99 are about 0.7 the corresponding values determined by Shepard & Lindgren (1934) for the longer exposure and lower temperature, but they approach

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[2] The aid of Mr. L. L. Stitt in making some of the tests, and of Mrs. L. L. Stitt in laboratory assistance is acknowledged.

[3] Preliminary resumes of this work were published in: Report on Agricultural Research for the year ending June 30, 1943. II. Iowa Corn Research Inst. 8th Ann. Report pp. 58–60, and in Proc. 33rd Ann. Meeting North Central States Entomologists, Urbana, Illinois, March 1944, p. 25.

closely the LD50 value obtained by Shepard *et al.* (1937) at the same temperature and 5-hour exposure. The LD99 values, however, differ widely. Gunderson's work reveals much less difference in toxicity between carbon tetrachloride and carbon disulfide than had been reported previously. Cotton & Wagner (1941) recommended the standard ethylene dichloride-carbon tetrachloride mixture for wheat fumigation, and Farrar & Flint (1942) recommended it for corn fumigation, but neither, apparently, attempted to evaluate the components of the mixture. Jefferson (1943) found that carbon tetrachloride and ethylene dichloride were similar in their toxicity to *Tribolium castaneum* (Hbst.) in empty space at 30° C., and exposure of 2 hours. His data show the former compound to be 0.91 times as effective at LD50 and 0.71 times as effective at LD99 as ethylene dichloride. Comparison of these toxicity values for carbon tetrachloride with the corresponding values for *T. confusum* (Gunderson 1940) shows a close similarity in the susceptibility of the two species to this compound. While this investigation was in progress, Cotton (1944) and Cotton *et al.* (1945) reported results with carbon tetrachloride and with the standard ethylene dichloride-carbon tetrachloride mixture which indicate approximately equal efficiency of the 2 fumigants for the treatment of corn and wheat.

Notwithstanding some contradictions, the published record offered three important suggestions regarding the relative efficiency of carbon tetrachloride and ethylene dichloride: (1) The compounds are equal or nearly equal in effectiveness, under some conditions, to certain grain-infesting insects; (2) since the more critical tests were made in empty space, the results might be different in spaces filled with corn; (3) the more critical investigations were generally carried out at relatively short (2- to 5-hour) exposures; under the longer exposures prevailing in practice, seldom less than 24 hours, the compounds might show a different relative effectiveness.

The investigation was directed at once to an examination of these suggestions.

MATERIALS.—The test insects were adults of *Sitophilus oryza*, *Tribolium castaneum* and *Oryzaephilus surinamensis* cultured in whole corn or in a cereal mixture by procedures already described (Richardson & Walkden 1945).

The carbon tetrachloride, ethylene dichloride and the other compounds used in the investigation were of good commercial grade or better. All mixtures were made on a volume basis, the basis most frequently used in practice.

The corn used in these experiments ranged in moisture content from about 8 to 12 per cent, and was practically free from cracked kernels and foreign matter.

METHODS.—All tests were made in the laboratory usually at a constant temperature of 30° C. (86° F.). Some experiments were made, however, at room temperature. Exposures were always 24 hours or longer.

Tests were made in empty space (5.5-liter balloon flasks), in 5-gallon jars containing 5 pounds of corn, or in tin containers of 18.6 liters capacity charged with 27 pounds of corn. The first 2 types of test have already been described (Richardson & Walkden 1945). The tin containers provided a column of corn 17.5 inches in height with a space above it (overspace) equal to about 9.4 per cent of the volume of the container. In operation, caged samples of insects were placed in the following locations within the containers: (1) overspace; (2) top, about one kernel depth beneath the surface of the corn; (3) in the middle of the corn mass; (4) at the bottom of the corn mass. The fumigant was dropped onto the surface of the corn through a hole in the lid of the container. The containers were then sealed gas-tight, and held at room temperature throughout the exposure period.

The test insects were taken at random from large pooled groups of active individuals collected each day from vigorous cultures. The samples varied in size from about 50 to 150 individuals. For critical comparisons, tests were made concurrently with each species of insect in the following manner: Each day's testing included trials with the fumigants under comparison at 3 or 4 distinct dosage levels; this procedure was usually repeated on different dates until 2 to 5 replicate tests at each dose were completed. Unreplicated series of tests are so indicated by footnotes in the tables.

After exposure, the insects were held

at room temperature with access to food and moisture. The percentages of mortality were determined 5 days after the application of the fumigant, or if the exposure were longer, then immediately at the close of the exposure period. Dosage-mortality curves were calculated from the probit-logarithmic transformations of the corrected percentages of mortality and the dosages. The LD50, LD95 and other dosages were calculated from the equations for the curves.

CONTROLS.—Control samples accompanied each day's tests; the observed percentage of "natural" mortality was applied in correcting the experimental data by formula (Abbott 1925). If the control mortality in a culture were less than 5 per cent, and the culture had produced new insects not much longer than 1 month, the culture was considered a satisfactory source of test insects. If, however, the culture yielded samples with more than 5 per cent control mortality, it was not used. Doubtful cultures, and cultures which had not been drawn upon for some time, were sampled for control mortality before test insects were taken from them.

Considerable information now available on the test insects furnishes the following "natural" mortality values for the 5- to 6-day experimental period: *Sitophilus oryza* (38,000 insects) 1.99 per cent; *Tribolium castaneum* (26,000 insects) 2.24 per cent; *Oryzaephilus surinamensis* (9000 insects) 2.45 per cent. A part, possibly one-half, of this mortality may have resulted from abrasions and other injuries received during the handling of the insects. In 93 to 95 per cent of the samples, the maximum per cent of mortality was 6.2; in the experiments reported in this paper, the control mortality did not exceed 4.3 per cent. Some data are available for experimental series in which the control mortality was well above the 5-per cent level. The LD values calculated from these data departed significantly from those of series in which the normal mortality fell below the 5-per cent level. Control mortality, therefore, served as an indication of the general vigor of the test insects as well as for the correction of the mortality data.

TOXICITY IN EMPTY SPACE.—Carbon tetrachloride and ethylene dichloride were tested concurrently, and the standard mixture of these compounds was tested a year later against *Sitophilus oryza* in empty 5.5-liter flasks. The results of these experiments are shown in table 1.

Table 1.—Toxicity of carbon tetrachloride, ethylene dichloride and the standard ethylene dichloride-carbon tetrachloride mixture to *Sitophilus oryza* in empty space. Exposure 24 hours; temperature 30°C.

FUMIGANT	LD50[1]		LD95[1]		LD99.9[1]	
	cc. per Liter	Mg. per Liter	cc. per Liter	Mg. per Liter	cc. per Liter	Mg. per Liter
Carbon tetrachloride	0.040±0.002[2]	64	0.052	83	0.065	104
Ethylene dichloride	.023±0.002[2]	29	.036	45	.053	67
Standard ethylene dichloride-carbon tetrachloride mixture[3]	.024±0.002[2]	32	.042	56	.067	90

[1] The doses for 50, 95 and 99.9 per cent mortality respectively.
[2] Confidence limits for chances of 19 in 20.
[3] The mixture contained 75 per cent by volume of ethylene dichloride.

Ethylene dichloride was about twice as toxic as carbon tetrachloride in these experiments; under the same conditions of temperature and exposure, the standard mixture, in keeping with its composition, approached ethylene dichloride more closely in toxicity. The values for carbon tetrachloride agree satisfactorily with those reported by Shepard & Lindgren (1934) at 25° C.; but the values for ethylene dichloride are 2 to 3 times as large. The information presented in table 1 confirms previously reported work in showing that ethylene dichloride is more toxic to insects in empty space than carbon tetrachloride; it suggests, however, that this difference may not be so large as has sometimes been reported.

TOXICITY IN 5-POUND LOTS OF SHELLED

CORN.—Carbon tetrachloride and ethylene dichloride were tested on 3 species of corn-infesting insects located near the surface (top position) and at the bottom (6.5 inches below the surface) of corn in 1-gallon jars. Except for the carbon tetrachloride series (24-hour exposure) and the standard ethylene dichloride-carbon tetrachloride series, each couplet in the table is based on data from concurrent tests. The results are presented in table 2.

Table 2.—Effectiveness of carbon tetrachloride and ethylene dichloride in 5-pound lots of shelled corn. Temperature 30°C.

FUMIGANT	INSECT	EXPOSURE HOURS	POSITION OF INSECTS IN CONTAINER	LD50 CC. PER 5 LBS. CORN	LD95 CC. PER 5 LBS. CORN
Carbon tetrachloride	*Sitophilus oryza*	24	Top	0.171±0.011[1]	0.229
			Bottom	.160	.236
Ethylene dichloride	*Sitophilus oryza*	24	Top	.259±0.011[1]	.426
			Bottom	.287	.388
Carbon tetrachloride[2]	*Tribolium castaneum*	24	Top	.136	.174
			Bottom	.129	.164
Standard ethylene dichloride-carbon tetrachloride mixture[2]	*Tribolium castaneum*	24	Top	.247	.370
			Bottom	.250	.316
Carbon tetrachloride	*Tribolium castaneum*	72	Top	.204	.298
			Bottom	.178	.280
Ethylene dichloride	*Tribolium castaneum*	72	Top	.163	.240
			Bottom	.162	.277
Carbon tetrachloride	*Tribolium castaneum*	168	Top	.165	.199
			Bottom	.157	.196
Ethylene dichloride	*Tribolium castaneum*	168	Top	.153	.183
			Bottom	.161	.209
Carbon tetrachloride	*Oryzaephilus surinamensis*	24	Top	.150	.214
			Bottom	.136	.191
Ethylene dichloride	*Oryzaephilus surinamensis*	24	Top	.152	.346
			Bottom	.153	.344

[1] Confidence limits for chances of 19 in 20.
[2] The experiments were not made concurrently.

Table 2 shows the almost complete disappearance in the presence of corn of a distinctive difference in toxicity between carbon tetrachloride and ethylene dichloride. In fact, the most pronounced difference points in the opposite direction as the figures for *Sitophilius oryza* illustrate. At exposures greater than 24 hours, the 2 compounds appear to be about equally toxic to *Tribolium castaneum*. The figures for the standard mixture against *T. castaneum* (24-hour exposure), and those for ethylene dichloride against *S. oryza* agree rather closely as would be expected on the basis of equal susceptibility of the 2 species to both compounds. The figures for carbon tetrachloride against *T. castaneum* (24-hour exposure), obtained early in the course of the investigation, appear somewhat low in comparison with the determinations made later at longer exposures. *Oryzaephilus surinamensis* seems to be the least resistant of the 3 species used in this study. However, the actual differences in species resistance to these compounds are not large, and they are probably of no great practical significance.

Loss of toxic efficiency by ethylene dichloride in the presence of shelled corn appears to be due, in large part at least, to sorption of the gas by the corn. An indication of the extent of sorption may be seen from the following calculations: The space above the corn in the 1-gallon jar contain-

ing 5 pounds of corn is 356 cc.; the volume occupied by the corn is 3430 cc.; approximately 40 per cent of this volume (Zink 1935) or 1372 cc., represents kernel interspace; the total air space in the jar is therefore 1728 cc. The LD50 of carbon tetrachloride for *S. oryza* in 1728 cc. of free space would be 0.069 cc. (from Table 1), and for ethylene dichloride it would be 0.040 cc. The LD50 of carbon tetrachloride near the surface of 5 pounds of corn (Table 2) is 0.171 cc., or 2.5 times the free-space dosage. For the same kill with ethylene dichloride 6.5 times the free-space dosage is required. The ratio, 2.5:6.5, gives an approximate measure of the apparent relative sorption of the 2 compounds in corn. It shows that corn takes up under the experimental conditions significantly larger quantities of ethylene dichloride than of carbon tetrachloride, quantities sufficient, in fact, to nullify the inherently greater toxic advantage of ethylene dichloride.

TOXICITY IN 27-POUND LOTS OF SHELLED CORN.—Experiments with these fumigants were made at room temperature in large tin containers holding 27 pounds of corn. *Sitophilus oryza* and *Tribolium castaneum* were the test insects. The results are given in table 3.

Carbon tetrachloride gave complete control of *Tribolium castaneum* in all locations except the overspace at the lowest dosage. It was more efficient in these unreplicated tests than in the small-lot experiments (Table 2). Ethylene dichloride, on the other hand, gave satisfactory kills only at the highest dosage, and agreement was satisfactory with the equivalent dosage for 72 hours in the small-lot experiments. Mortality in the overspace and top location from each dose of ethylene dichloride was similar and usually lower than the mortality in the middle and bottom locations.

Failure to achieve control in the surface is a phenomenon of frequent occurrence in the commercial fumigation of corn. Loss of the fumigant by volatization into the overspace is no doubt responsible in part for this failure, especially where considerable leakage occurs. In this experiment, where leakage was prevented, the intrinsically greater toxicity of ethylene dichloride disappeared, just as it did in the small-lot experiments, owing largely to sorption of the compound by the corn.

The tests with *Sitophilus oryza* (Table 3) failed to reveal differences of practical significance between carbon tetrachloride, ethylene dichloride and the standard mixture. Significant differences, owing to location of the test insects in the containers, vanished at the high dosages used. The lowest dose tested (2.00 cc. per 27 pounds), equivalent to 0.37 cc. on the 5-pound basis, and to 1.1 gallons per 1000 bushels at field dosage, agrees closely with the LD50 value of 0.388 cc. per 5 pounds for ethylene dichloride (*S. oryza*, bottom

Table 3.—Effectiveness of carbon tetrachloride, ethylene dichloride, and the standard ethylene dichloride-carbon tetrachloride mixture against two species of insects in 27-pound lots of shelled corn. Room temperature (19-26° C).

Fumigant	Insect	Dosage			Percentage of Mortality in:			
		cc./27 Lb. Corn	cc./5 Lb. Corn	Gal. per 1000 Bu.	Over-space	Top	Middle	Bottom
Carbon tetrachloride	*Tribolium castaneum*[1]	0.93	0.17	0.51	96.7	100	100	100
Ethylene dichloride	" "	.93	.17	.51	8.3	13.1	46.9	49.8
Carbon tetrachloride	" "	1.08	.20	.59	100	100	100	100
Ethylene dichloride	" "	1.08	.20	.59	67.3	64.7	92.2	86.4
Carbon tetrachloride	" "	1.40	.26	.77	100	100	100	100
Ethylene dichloride	" "	1.40	.26	.77	87.9	82.2	96.2	98.1
Carbon tetrachloride	*Sitophilus oryza*[2]	2.00	.37	1.10	97.8	96.7	98.5	96.0
Ethylene dichloride	" "	2.00	.37	1.10	94.5	95.6	98.5	95.2
Standard Mixture	" "	2.00	.37	1.10	95.9	96.9	92.0	95.1
Carbon tetrachloride	" "	3.00	.56	1.64	97.4	96.6	99.3	98.8
Ethylene dichloride	" "	3.00	.56	1.64	100	100	100	100
Standard Mixture	" "	3.00	.56	1.64	94.8	97.8	100	99.9
Carbon tetrachloride	" "	4.00	.74	2.19	99.2	99.8	99.5	99.8
Ethylene dichloride	" "	4.00	.74	2.19	100	99.7	99.6	100
Standard Mixture	" "	4.00	.74	2.19	100	100	99.7	100

[1] Exposure 72 hours; single tests with samples of about 150 insects at each dosage.
[2] Exposure 24 hours; tests repeated 2 to 4 times with samples of about 150 insects.

location) in table 2. This dose is somewhat higher than the corresponding dose for carbon tetrachloride, and nearer the LD99.9 value of 0.332 cc. per 5 pounds calculated for that compound. The general agreement between the data for the large lot and small lot experiments appears satisfactory in view of the differences in experimental conditions and apparatus. The 3.00 cc. and 4.00 cc. carbon disulfide and 1,1-dichloro-1-nitroethane in 6 proportions, and with β-methylallyl chloride and 1,1-dichloro-1-nitroethane in 1 proportion were tested against *Tribolium castaneum* and *Oryzaephilus surinamensis* in 5-pound lots of shelled corn. The results are given in table 4.

The 20–80 per cent carbon disulfide-carbon tetrachloride mixture was about as effective in these experiments as carbon

Table 4.—Effectiveness of carbon tetrachloride mixtures in 5-pound lots of corn. Exposure 24 hours; temperature 30°C.

Fumigant	Percentage of Components by Volume	Insect	Position in Container	Results: LD50 cc./5 lbs. Corn	Results: LD95 cc./5 lbs. Corn
Carbon disulfide-carbon tetrachloride mixture[1]	80–20	*Tribolium castaneum*	Top Bottom	0.062 .064	0.085 .084
do	50–50	do	Top Bottom	.080 .076	.129 .110
do	20–80	do	Top Bottom	.129 .124	.202 .182
Carbon disulfide-1,1-dichloro-1-nitroethane-carbon tetrachloride mixture	20– 0–80[2]	*Oryzaephilus surinamensis*	Top Bottom	.171 .162	.227 .206
	15– 5–80[2]	do	Top Bottom	.106 .104	.133 .127
do	10–10–80[2]	do	Top Bottom	.063 .062	.091 .078
do	5–15–80	do	Top Bottom	.038 .043	.059 .061
do	0–20–80	do	Top Bottom	.030 .033	.042 .049
do	5– 5–90	*Tribolium castaneum*	Top Bottom	.159±0.010[3] .141	.226 .206
β-Methylallyl chloride-1,1-dichloro-1-nitroethane-carbon tetrachloride mixture	5– 5–90	do	Top Bottom	.124±0.010[3] .119	.174 .147

[1] Exposure 30 hours.
[2] Unreplicated tests.
[3] Confidence limits for chances of 19 in 20.

dosages gave almost complete mortality with the 3 fumigants in all locations. The latter is approximately the dosage of carbon tetrachloride recommended by Doane a quarter of a century ago for the control of weevils in wheat.

TOXICITY OF THE OTHER CARBON TETRACHLORIDE MIXTURES IN CORN.—Mixtures of carbon tetrachloride with carbon disulfide in 3 proportions, with tetrachloride alone (Table 2). This mixture contains the maximum proportion of carbon disulfide that can be used where fire hazard is an important consideration.

The 3-component mixtures of carbon disulfide, 1,1-dichloro-1-nitroethane, and carbon tetrachloride became increasingly more toxic as the proportion of 1,1-dichloro-1-nitroethane was increased. Mixtures containing 15 and 20 per cent of

this compound were among the most toxic fumigants tested in this study. Substitution of β-methylallyl chloride for carbon disulfide in the mixtures containing 90 per cent carbon tetrachloride led to slightly enhanced effectiveness.

OTHER COMPOUNDS.—Table 5 presents the results of tests with 9 compounds on 1 of the jars. Allyl chloride resembles β-methylallyl chloride (Richardson & Walkden 1945); it was about as toxic in corn as carbon disulfide. Compared with carbon tetrachloride (table 2), trichloroethylene was apparently less effective although the difference is not large. Neither propylene dichloride nor 1,1,2-

Table 5.—Effectiveness of nine compounds against three species of insects in 5-pound lots of corn. Temperature 30° C.

FUMIGANT	INSECT	EXPOSURE HOURS	POSITION IN CONTAINER	LD50 CC./5 LBS. CORN	LD95 CC./5 LBS. CORN
Carbon disulfide	*Tribolium castaneum*	24	Top	0.055	0.083
			Bottom	.057	.081
do	do	72	Top	.041	.049
			Bottom	.040	.049
do	*Oryzaephilus surinamensis*	24	Top	.067	.091
			Bottom	.067	.090
Propylene dichloride	*Tribolium castaneum*	do	Top	.187	.229
			Bottom	.193	.254
do	*Oryzaephilus surinamensis*	do	Top	.191	.284[1]
			Bottom	—	—
Trichloroethylene	do	do	Top	.231	.397
			Bottom	.218	.379
do	*Sitophilus oryza*	do	Top	.207	.327
			Bottom	.188	.324
Isocrotyl chloride	do	do	Top	.173	.269
			Bottom	—	—
Isopropyl formate	do	do	Top	.110	.164
			Bottom	.104	.145
2-Chlorobutene-2	do	do	Top	.241	.322
			Bottom	.233	.313
Methylisopropenyl ketone	do	do	Top	.023	.032
			Bottom	.044	.061
Allyl clhloride[2]	do	do	Top	—	—
			Bottom	.049	.067
1,1,2-Trichloroethane[2]	do	do	Top	—	—
			Bottom	.134	.244

[1] Extrapolated value.
[2] Tests made by C. C. Blickenstaff.

or several of the 3 species of insects used in this study. The tests were made in 5-pound lots of corn.

Methylisopropenyl ketone ranks highest in effectiveness near the corn surface, but it was so markedly sorptive that the dosage had to be increased by 2 to penetrate and kill the insects in the bottom

trichloroethane showed marked superiority over carbon tetrachloride. 1,1,2-Trichloroethane also proved no more toxic than carbon tetrachloride under similar conditions to the resistant *Tenebroides mauritanicus* (Richardson 1945).

EFFECT OF CARBON TETRACHLORIDE ON MAN.—Carbon tetrachloride is a rela-

tively safe compound to handle in fumigating operations. Nevertheless, it is a poison, and certain precautions should be taken whenever exposure to its vapors is necessary. The maximum concentration of carbon tetrachloride considered safe for prolonged exposure is 100 parts per million, equivalent to about 0.04 pound (0.003 gallon) per 1000 cubic feet of space (Henderson & Haggard 1943). Recent information however, suggests a downward revision of this limit to 50 (Hamilton 1943) or even to 32 parts per million (Lehmann & Flury 1943). It is interesting to notice in this connection the similar downward trend in the concentration of carbon tetrachloride found necessary for effective insect toxicity.

Operators who are forced to work in closed spaces where carbon tetrachloride vapors exist should be provided with adequate gas masks. Rooms that have been fumigated should be thoroughly ventilated before they are occupied.

EFFECT OF CARBON TETRACHLORIDE ON THE GERMINATION OF SEED CORN.—A few references to the effect of carbon tetrachloride on the germination of corn have been found in the literature, but they furnished little indication of the tolerance of seed corn for this fumigant.

A sample of hybrid seed corn of 8.2 per cent moisture content was, therefore, exposed to a widely-ranging series of carbon tetrachloride dosages. The seed, in 5 pound lots, was sealed in gas-tight 1-gallon jars and maintained at a constant temperature of 30° C. for 7 days. At the end of this time, the seed was removed and aerated for 7 to 13 days at room temperature; then samples of 400 seeds were tested for germination in sand cultures at 80° F. (sand test), and some of the samples were germinated in sand at 50° F. (cold test). Only one of the cold-tested samples was treated with a fungicide (commercial organo-mercury preparation) before planting. Three lots of seed that were subjected to the higher dosages were tested again (sand test) after they had remained in glass jars with loosely fitting lids for 80 to 116 days. The results of these tests are given in table 6.

Dosages up to 38.2 gallons per 1000 bushels failed to reduce significantly the percentage of germination of the seed. The cold-tested seed gave low germination values apparently because it was not treated with a fungicide before planting; but there is no indication that the carbon tetrachloride contributed to this harmful effect. All dosages higher than 38.2 gallons progressively depressed germination, but they failed to kill all of the seed, and after long contact with the air, the seed recovered 87 to 97 per cent of the control value.

Table 6.—Effect of carbon tetrachloride on the germination of seed corn. Exposure 7 days; temperature 30° C; moisture content of seed 8.2 per cent.

Dosage Gals. per 1000 Bu.	Number of Replicates	Average Per Cent Germination	
		Sand Test	Cold Test
Untreated Control	3	93	
Untreated Control	1	—	55 (88)[1]
1.5	1	96	
3.6	1	96	
3.6	1	—	52
5.3	1	97	
8.5	1	94	
10.4	1	95	
10.4	1	—	59
13.2	1	94	
18.7	1	92	
20.4	1	91	
25.2	2	92	
38.2	2	88	
38.2	1	—	55
60.0	2	58 (90)[2]	
93.5	2	60	
148.2	2	56	
372.8	2	42 (86)[2]	
600.0	2	41 (81)[2]	

[1] Seed disinfected before planting.
[2] Germination in 80 to 116 days after exposure to carbon tetrachloride.

The jars which received the two highest dosages contained, after 7 days, a considerable volume of unabsorbed carbon tetrachloride, and the free space in the jars was saturated with carbon tetrachloride vapor. It may be concluded from this fact that there is little danger of reducing germination by pouring moderate insecticidal doses of carbon tetrachloride directly onto the seed.

It is probable that dosages greater than 10 gallons per 1000 bushels will not ordinarily be required for the control of corn-infesting insects in tight storage. Dry seed corn can, apparently, withstand

exposure to this dosage for a considerable time. As a precaution, however, it is recommended that exposure to such doses extend not longer than one week, and that the seed be aerated immediately afterward.

SUMMARY.—1. Carbon tetrachloride, ethylene dichloride, and the standard ethylene dichloride-carbon tetrachloride mixture (75 per cent by volume of ethylene dichloride) were tested in empty space and in containers holding 5 pound and 27 pounds of dry, shelled corn against 3 corn-infesting insects, *Sitophilus oryza*, *Tribolium castaneum*, and *Oryzaephilus surinamensis*. Methods are described.

2. In empty space at 30° C. and 24-hour exposure, ethylene dichloride was about twice as toxic as carbon tetrachloride. The standard mixture approached ethylene dichloride in toxicity.

3. In dry corn, the intrinsically greater toxicity of ethylene dichloride disappeared owing to sorption by the corn, and the two compounds became similar in toxicity.

4. Carbon disulfide-carbon tetrachloride mixture (20 per cent by volume of carbon disulfide) proved about as toxic in corn to *Tribolium castaneum* as carbon tetrachloride itself.

5. In three-component mixtures of carbon disulfide, 1,1-dichloro-1-nitroethane and carbon tetrachloride, the compositions with 15 to 20 per cent by volume of 1,1-dichloro-1-nitroethane were highly toxic in shelled corn to *Oryzaephilus surinamensis*. In preliminary tests with *Tribolium castaneum*, β-methylallyl chloride was more efficient than carbon disulfide in these mixtures.

6. Methylisopropenyl ketone is highly toxic to *Sitophilus oryza*, but it is strongly absorbed by the corn.

7. Carbon tetrachloride is at least as effective in shelled corn as trichloroethylene, propylene dichloride, and 1,1,2-trichloroethane.

8. Carbon tetrachloride is a safe fumigant to handle if ordinary precautions are taken. Even short exposures, in closed spaces, to effective insecticidal dosages may be dangerous without the protection of a gas mask.

9. Effective dosages of carbon tetrachloride will not injure the germination of seed corn even when the fumigant is poured directly onto the corn. Exposures longer than one week in tight containers are not recommended. The seed should be aerated thoroughly at the close of the exposure period.

10. For the treatment of corn in gastight structures, 2 gallons of carbon tetrachloride per 1000 bushels for 24 hours or longer at temperatures of 70° F. or above will control the 3 species of insects used in this investigation. Under good fumigating conditions with respect to leakage etc., a somewhat higher dosage (3 to 4 gallons) may be required for commercial control.—7-20-46.

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Redrying of Tobacco and Its Effect on Insect Infestation

JOSEPH N. TENHET and C. O. BARE,[1] *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

All tobacco is subject to insect damage in storage, and the annual loss from this source is estimated to be in excess of $10,000,000. Flue-cured, or cigarette, tobacco, the most important type produced in the United States, is particularly subject to insect attack. When marketed by the farmer, leaf tobacco usually has a high moisture content and is therefore subject to molds, rots, and insect infestation. To protect the tobacco, drying is necessary. Cigarette tobacco is normally aged about 30 months before being manufactured, and it is during this period in storage that the heaviest losses occur. Tobacco may become infested with the tobacco moth, *Ephestia elutella* (Hbn.), or the cigarette beetle, *Lasioderma serricorne*, (F.), while on the farm or in the auction-sales warehouse, and it is desirable to know whether such infestation is likely to be carried into storage.

The commercial process by which the moisture content of tobacco is regulated in its preparation for storage is known as redrying. In this process the tobacco is passed through a long chamber, where it is subjected to heat to drive off all moisture. Live steam is then introduced to supply the exact amount of moisture required. The moisture content of redried tobacco usually ranges from 10 to 11.5 per cent. Tobacco is removed from a redrying machine, packed directly into hogsheads, and compressed under hydraulic pressure. All flue-cured tobacco is redried, and there has been evidence that the process kills many insects.[2] However, no adequate proof has previously been obtained of the effectiveness of this redrying process in killing insects. Tobacco being packed for export is processed for a longer period and at higher temperatures than that intended for domestic manufacture. Consequently, the chance for insect survival would be greater in tobacco packed for domestic consumption. Because of this fact, all tests described in this paper were conducted with tobacco being processed for domestic use.

REDRYING OF LEAF TOBACCO.—Leaf tobacco is usually received tied in bundles, or "hands," of 15 to 20 leaves. Four test lots of insects, each lot consisting of 10 or more individuals[2] of each stage of both the tobacco moth and the cigarette beetle, were placed in tiny wire-gauze cages, which were inserted into the butts of hands of tobacco. In this position the insects received the maximum amount of protection from the tobacco. The hands of tobacco were then hung on a stick and the stick was placed on the conveyor as it entered the redrying machine. Thus, for each test 40 or more individuals of each stage of both insects were used.

The length of the operating cycle and the temperatures employed to redry

[1] The writers wish to express their appreciation to W. D. Reed and J. P. Vinzant for preliminary work with the redrying process in 1938. Unpublished reports of their work confirm the results here given.

[2] 10 of each stage, except that 25± eggs were used.

tobacco vary with each type, grade, and condition of tobacco being processed. The length of the operating cycle for leaf tobacco customarily ranges from 43 to 80 minutes, and the maximum temperature from 195° to 230° F. During this experiment the operating cycles ranged from 43 to 57 minutes and the maximum temperature from 195° to 224° F. The machine was a standard redrying machine of a type in common use, and all tests were conducted under commercial operating conditions. The hands of tobacco, hung on 4.5 foot sticks (20 to 25 hands to a stick), were carried by the endless conveyor on which they were passed slowly through the machine (Fig. 1).

The tobacco first passed through the drying chamber, consisting of three areas

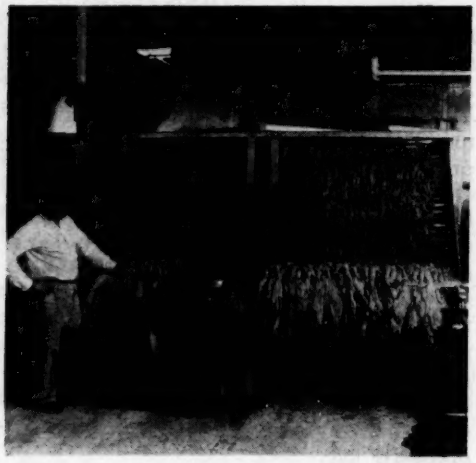

FIG. 1.—Sticks of leaf tobacco in hands, entering a redrying machine.

of different temperatures (the middle area having the highest temperature). There the tobacco was dried by the forced circulation of hot air. The passage of the tobacco through the drying chamber required 20 minutes of a 43-minute cycle.

On leaving the drying chamber the tobacco entered the steam chamber, where superheated steam was introduced at a temperature of approximately 300° F. However, as the steam left the jets and expanded, the temperature dropped very rapidly, so that by the time it reached most of the tobacco the temperature was probably lower than 200°. The amount of steam introduced into this chamber and the time required for passage through it determined the amount of moisture that was replaced in the tobacco. Usually the time required for tobacco to pass through the steam chamber was approximately the same as that required for passage through the drying chamber. From the steam chamber the tobacco passed on into a cooling chamber, where the temperature was dropped to 120–130°. Passage through this chamber required 3 minutes of a 43-minute cycle.

The experiment to test the insect-killing effect of the redrying process was replicated 8 times. Then to obtain additional information as to what part of the process kills insects, 8 more replications were made, in which the tobacco was passed through the drying chamber only, and in 8 others it was passed through the steam and cooling chambers only. In these experiments only larvae and pupae of the cigarette beetle and the tobacco moth were used, as those stages seemed to be the most resistant.

RESULTS.—In each test with the complete redrying process the mortality of all stages of both insects was 100 per cent. In the tests where larvae and pupae were passed through the drying chamber only, the mortality was high, but in one replication a few pupae of each species survived. In the experiment where larvae and pupae were passed through the steam and cooling chambers only, mortality was not consistent. It ranged from 100 per cent to none but in each replication there was some survival in one or more of the stages (Table 1). In every test there was an ap-

Table 1.—Mortality of larvae and pupae of the cigarette beetle and the tobacco moth in tobacco that passed through the steam and cooling chambers only. Richmond, Va., 1944.

	Cigarette Beetle		Tobacco Moth	
Replicate	Larvae	Pupae	Larvae	Pupae
	Per cent	*Per cent*	*Per cent*	*Per cent*
1	2.5	0	70	25
2	5	17.5	77.5	50
3	5	10	100	97.5
4	10	100	100	97.5
5	12.5	2.5	40	25
6	20	0	52.5	37.5
7	100	17.5	100	100
8	72.5	32.5	100	100
Check	1.25	0	0	36.25

preciable survival of at least one stage.

REDRYING OF STEMMED TOBACCO.—Stemmed tobacco, or "strips," is leaf tobacco from which the large midrib has been removed. This leaves only the softer parts of the leaf. Much flue-cured tobacco, both for export and for domestic manufacture, is stemmed prior to storage. Stemming is often done after the tobacco has been redried and stored, and the strips are again redried before being packed into hogsheads. In the stemming process the hands of leaf tobacco are broken up, and the strips come from the stemming machines in the form of a loose mass of soft fragments of leaf. This tobacco is passed through a redrying machine on an apron, or endless belt, ranging from 5 to 10 feet in width. The belt is formed of quarter-inch wire mesh. The tobacco on the belt is in a layer 4 to 8 inches thick, and the operation is very similar to the redrying of leaf tobacco.

The important difference between the redrying of leaf and of strips is in the length of the operating cycle and the temperatures employed. The most difficult part of drying leaf tobacco lies in getting the moisture out of the midrib. Since there are no midribs in stemmed tobacco, the process can be speeded up and lower temperatures employed. The operating cycle of a redrying machine for tobacco strips usually ranges from 9 to 30 minutes and the maximum temperature employed seldom exceeds 165° F. Because of this shorter period of exposure and the lower temperatures involved, the chance for insect survival is greater. However, the shorter period and the lower temperatures are partly compensated for by the fact that the heat and steam can penetrate the tobacco more readily.

In this experiment 8 replications were completed in which all stages of both the tobacco moth and the cigarette beetle were passed through the entire machine for redrying stemmed tobacco. In these tests the insects were confined in the small wire-gauze cages previously described, and then the cages were loosely tied in white cheesecloth bags. The bags were buried in the layer of tobacco that was passing through the machine. The operating cycle was 9 to 10 minutes.

RESULTS.—In only one test of the 8 replicates was there any insect survival, a single pupa of the cigarette beetle.

SUMMARY AND CONCLUSIONS.—An adequately replicated experiment was conducted to test the insect-killing effect of the commercial process for redrying tobacco. It was shown that the redrying of leaf tobacco caused 100 per cent mortality of all stages of the tobacco moth, *Ephestia elutella* (Hbn.), and the cigarette beetle, *Lasioderma serricorne* (F.). Most of this mortality occurred in the drying chamber of the process, and was probably due to a combination of heat and desiccation.

The redrying of stemmed tobacco is performed more rapidly and at lower temperatures than of leaf tobacco, and is not completely effective in destroying all stages of insect life. However, it does kill most of the insects present.

It appears, therefore, that redried leaf tobacco can be safely assumed to be free of insect infestation when it enters storage. Redried tobacco strips will probably be free of insect infestation, but it is always possible that a few insects may have survived the process.—7-1-46.

PERSONNEL CHANGES AT WISCONSIN

Recent changes and new appointments to the staff of the Department of Economic Entomology, University of Wisconsin, are announced as follows:

Dr. T. C. Allen, Professor and Chairman, Insecticides and Vegetable Insects.
Dr. Floyd Andre, Professor of Economic Entomology and Assistant Director of the Experiment Station.
Dr. John T. Medler, Assistant Professor (Half-time in Agronomy) Forage Crop Insects.
Dr. Robert J. Dicke, Assistant Professor, Dairy and Storage Products Insects.
Dr. Roy D. Shenefelt, Assistant Professor, Forest Insects.
Mr. E. H. Fisher, Assistant Professor, Extension Specialist.
Mr. R. K. Chapman, Instructor, Vegetable Insects.

Other personnel:

Dr. C. L. Fluke, Professor, Orchard Insects.
H. F. Wilson, Professor, Pea Aphid Investigations.
Dr. C. L. Farrar, Professor, Apiculture.
Dr. J. H. Lilly, Associate Professor (Half-time in Zoology) Corn Insects.
Mr. William C. Roberts, Instructor, Apiculture.

Reaction of Hornworms to Certain Organic Compounds

C. F. Stahl, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Flue-cured tobacco grown in North Carolina is infested each season by two species of hornworms—the tobacco hornworm, *Protoparce sexta* (Johan.), and the tomato hornworm, *P. quinquemaculata* (Haw.). In the Oxford area the tomato hornworm has been of little economic importance, although the adults collected in moth traps throughout a season may outnumber those of the tobacco hornworm. Seasonal surveys have shown that the tomato hornworm seldom makes up more than 10 per cent of the total field population. In some tobacco-producing districts in other states, however, this species is of major importance and control measures are directed mainly against it. It is possible that from time to time certain conditions may exist in North Carolina which permit the tomato hornworm to develop in large numbers and to require major consideration in the control program.

During the last 10 years studies on the control of hornworms attacking tobacco have been directed largely toward the discovery of an effective insecticide that would not leave a dangerous or unsightly residue on the mature plants. Inasmuch as the presence of arsenic on the cured tobacco leaves may possibly affect the health of the consumer, special emphasis has been placed on experiments designed to determine the toxicity of organic compounds to hornworms. Since the establishment of the Oxford, N. C., laboratory in 1935, tests with new organic compounds have been conducted each season to determine their toxicity to hornworm larvae infesting flue-cured tobacco. Prior to 1942 approximately 160 compounds had been tested (Stahl *et al.* 1945), but none had shown special promise for the practical control of hornworms. The tests were exploratory, without sufficient replication to establish relative values, and the tobacco hornworm was used exclusively as the test insect.

In 1942, replicated tests designed to compare the toxicity of some new organic compounds with that of cryolite were started. Both species of hornworms were utilized in these tests. Since the periods of development of these two hornworms do not coincide, it was not always possible to have an adequate supply of larvae of both species on hand at the same time. Whenever possible, however, the two species were tested on the same dates.

After a few tests had been completed, it was evident that the two species were not alike in their susceptibility to the toxic effects of organic compounds. It is the purpose of this paper to present data showing the differences in the reactions of the two species of hornworms to certain organic compounds. The results of tests conducted during 1943 and 1944 are cited, because the compounds utilized were the same and the series were replicates, except that in 1943 comparisons were not made on the same dates.

Procedure.—The technique employed was uniform for all tests. Adults were trapped and placed in large oviposition cages, where they were allowed to deposit eggs on tobacco plants growing in 10-inch flower pots. The pots were then transferred to the insectary, where the larvae were permitted to develop to third instars, which were used in the tests.

Fresh tobacco suckers were fitted in 4-ounce bottles containing water. The bottles were then placed individually in a settling chamber into which 150 mg. of the material was blown at a pressure of 30 pounds per square inch. The dust was allowed to settle on the tobacco sucker for 2 minutes. Each bottle was transferred to a screen-cylinder cage, and 10 larvae were placed on each sucker. These cages were examined daily for 4 days, and records of mortality, development, and feeding were made. Four samples of 10 larvae each were used in each replicate. The tests were replicated by dates, the number depending on the available supply of larvae.

The following organic compounds were tested in both 1943 and 1944: *p*-aminoazobenzene hydrochloride, *p*-aminoazobenzene, and phthalonitrile. Cryolite containing approximately 90 per cent of sodium fluoaluminate was included for comparison. Each material was thoroughly mixed with an equal part by weight of diatomaceous earth.

Diazoaminobenzene, diluted with an equal part of diatomaceous earth, was included in the 1943 tests. In 1944 a dust containing 10 per cent of technical DDT in pyrophyllite was substituted for diazoaminobenzene. This mixture was at first diluted with an equal part of diatomaceous earth but, inasmuch as the mixture had no effect on the tobacco hornworm minimum effective strength has not been determined. Treatment with DDT at a strength of 2.25 per cent has resulted in 100 per cent mortality within 48 hours.

The relative susceptibility of the two species of hornworms to the compounds tested is indicated to some extent by the rapidity of action. In tests with cryolite the maximum mortality for both species

Table 1.—Comparative effects of certain organic compounds on the tobacco hornworm and the tomato hornworm.

Compound	Average Mortality				Average Development		Feeding	
	1943 Tests		1944 Tests					
	Tobacco Hornworm	Tomato Hornworm	Tobacco Hornworm	Tomato Hornworm	Tobacco Hornworm	Tomato Hornworm	Tobacco Horn worm	Tomato Hornworm
	Per Cent	*Per Cent*	*Per Cent*	*Per Cent*				
p-Aminoazobenzene hydrochloride	36	97	25	94	Slight	Very slight	Slight	Very slight
p-Aminoazobenzene	24	92	22	94	do.	do.	do.	do.
Phthalonitrile	64	41	26	41	Moderate	Moderate	Moderate	Moderate
Diazoaminobenzene	22	75	—	—	Slight	Very slight	Slight	Very slight
DDT-pyrophyllite (1:9)	—	—	64	100	Moderate	None	do.	Very slight
Cryolite (check)	56	82	39	40	do.	Slight	do.	Moderate
Undusted check	5	1	0.35	2	Normal	Normal	Normal	Normal

larvae at this strength, the 10 per cent dust, without further dilution, was used in all the tests conducted for comparison of the effects of DDT on the two species. The data representing the 1943 tests were based on four replicates for the tomato hornworm and six for the tobacco hornworm. Seven replicates for both species were completed in 1944.

DISCUSSION.—The data are summarized in table 1. It is evident that the tomato hornworm is more susceptible to the toxic effects of the compounds tested, with the possible exception of phthalonitrile, than is the tobacco hornworm. Phthalonitrile has been tested many times, and its performance has been erratic, probably because of its comparatively volatile nature. It is possible that the compound is unstable. In many ways its effect on hornworms resembles that of DDT. The dead larvae have much the same appearance as those killed by DDT. The effect is rapid, but the larvae that survive the first 2 days after exposure to phthalonitrile usually feed and develop normally.

The extreme susceptibility of the tomato hornworm to DDT is interesting. A number of additional tests have been conducted in which different strengths have been employed, but as yet the was observed on the second day. With the tomato hornworm the maximum mortality from phthalonitrile occurred during the first 24 hours, and with the tobacco hornworm after 48 hours. With the tomato hornworm the maximum mortality due to *p*-aminoazobenzene hydrochloride and *p*-aminoazobenzene was noted on the second day, but with the tobacco hornworm the maximum mortality from *p*-aminoazobenzene hydrochloride was noted on the third day and from *p*-aminoazobenzene on the fourth day. Ninety-nine per cent of the tomato hornworm larvae succumbed to DDT during the first day, whereas the maximum mortality of the tobacco hornworm larvae was not reached until the fourth day.

CONCLUSIONS.—The organic compounds so far tested have shown little effectiveness against the tobacco hornworm. However, a few—diazoaminobenzene, *p*-aminoazobenzene hydrochloride, and DDT—have been surprisingly effective against the tomato hornworm. It seems probable that, where the tomato hornworm is the prevalent species, some of the available organic compounds might be more effective than any of the arsenical and fluorine insecticides available at the present time.—8-31-46.

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Effect of the Thermal-Vacuum Process on Insects in Stored Tobacco

C. O. BARE, JOSEPH N. TENHET, and W. D. REED,[1] *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Cigarette-type tobaccos are normally held in storage for about 30 months for aging. During this period flue-cured tobacco is often infested by the cigarette beetle, *Lasioderma serricorne* (F.), and the tobacco moth, *Ephestia elutella* (Hbn.). Losses of tobacco in storage are high and control of insects is a serious problem. In many cases, however, insect infestation in stored tobacco does not attract so much attention as infestation after manufacture. In the manufactured product—cigarettes, cigars, and pipe or chewing tobacco—insect infestation means not only a loss of the infested product but also a loss of the customer's good will. It is essential that the infestation of tobacco in storage not be carried over into the manufactured product.

In modern tobacco-manufacturing plants most of the tobacco is treated in a thermal vacuum. Tobacco as it comes out of storage is dry and brittle and cannot be handled without loss from breaking and crumbling. It is therefore necessary to condition it by adding moisture. This was formerly accomplished by placing the tobacco in a room of high relative humidity for several days, but a machine that accomplishes the same result in less than 30 minutes is now in use. The tobacco in hogsheads is placed in a vacuum tank and the air is exhausted to a vacuum of more than 29 inches as measured on a standard mercury gauge. Live steam is then introduced into the chamber, and quickly penetrates the entire mass of tobacco.

It has been known for several years that the thermal vacuum process kills many insects (Reed & Vinzant 1942). When the process was introduced in 1935, it was found that eggs and larvae of the cigarette beetle and the tobacco moth were killed by the treatment. Data have been lacking, however, to prove the complete effectiveness of this process in destroying insect life. The question is important, for upon its answer depends the necessity for additional treatment. In order to obtain final evidence on the subject, a carefully replicated experiment was conducted in the summer of 1944. All tests were conducted under commercial conditions, with regular factory personnel handling the equipment. Six replicates of the experiment were completed.

Test lots of insects consisting of 50 adults, 25 eggs, 10 larvae, and 10 pupae of the cigarette beetle and 10 larvae and 10 pupae of the tobacco moth (the two stages considered most resistant) were placed in small wire-gauze cages. These cages were then placed in perforated hollow metal spikes, a stave was removed from each hogshead, and through the opening thus made the spikes were driven into the tobacco. By this means the lots of test insects were inserted into the mass of tobacco at depths of 1.5 to 9.5 inches. The depth at which each stage of either insect was placed in the tobacco was random for each replicate of the experiment. For each test or replicate 5 cages of each stage of insect were prepared. Four cages were treated and the fifth was held as a check. Four hogsheads of tobacco were used in each test, which was one-half the number processed at one time.

The vacuum chamber consisted of a steel cylinder approximately 5.5 feet in diameter and 40 feet long. At both ends heavy doors closed against rubber gaskets. Evacuation of the cylinder was accomplished by means of aspirators utilizing steam at a pressure of about 95 pounds per square inch. In making a treatment the procedure was to exhaust the air until a vacuum of 29.5 inches was

[1] Now with U. S. War Department.

registered on a standard mercury gauge, and to hold this vacuum for 5 minutes. Live steam at a temperature of approximately 300° F. and a pressure of 95 pounds was slowly admitted until the vacuum within the cylinder was reduced to about 18.5 inches. The cylinder was then again evacuated to a reading of approximately 27.2 inches on a standard mercury gauge. This vacuum was held for 3 minutes, after which it was quickly released and the chamber was opened for the removal of the hogsheads.

The maximum temperature attained in the treated tobacco was estimated to range from 170° to 176° F. The total length of each treatment was approximately 16 minutes. After removal of the hogsheads from the vacuum chamber, the spikes were withdrawn from the tobacco and the insects were removed and held for observation. The mortality of larvae and adults was determined at the end of 24 hours, but eggs and pupae were kept under observation for 10 days. In all tests 100 per cent mortality of all stages was obtained.

In connection with this experiment, the question was raised as to the effect that a high vacuum has on insects. Repeated observations have indicated that a vacuum alone does not kill the cigarette beetle or the tobacco moth. Livingstone & Reed (1940) found water vapor to be an important factor affecting survival of the cigarette beetle and the tobacco moth at reduced pressure. Back & Cotton (1925) found that exposure to a 28- to 29-inch vacuum killed many species of insects, and that the mortality was increased by prolonged exposure. However, the maximum vacuum used by these workers was 29 inches. With the equipment used by the present writers a much higher vacuum was possible. The vacuum in the chambers could be reduced to 29.8 inches so rapidly that water placed in the machine would freeze in approximately 7 minutes, the period of vacuation. It seemed possible that such high vacuum with the accompanying sudden drop in temperature might kill insects in a short time. An unreplicated experiment on the effect of such a vacuum was therefore conducted.

Four test lots of 25 individuals of each stage of both the cigarette beetle and the tobacco moth were placed in the chamber and subjected to a high vacuum. A vacuum of 29.8 inches of mercury was reached in 7 minutes and held for 3 minutes. The period of release was 2 minutes. Room temperature at the time of the test was approximately 75° F.

Adults of the cigarette beetle were not affected, nor were the eggs of either species. The mortality of other stages was as follows: Cigarette beetle—larvae 21 per cent, pupae 36 per cent; tobacco moth—adults 8 per cent, larvae 11 per cent, pupae 13 per cent. In no instance was the mortality high enough to approach economic control.

SUMMARY AND CONCLUSION.—The thermal-vacuum treatment for conditioning tobacco is also effective in destroying insect life. Evidence is presented to show that tobacco treated by this process is freed of the cigarette beetle, *Lasioderma serricorne* (F.), and the tobacco moth, *Ephestia elutella* (Hbn.), and that infestation in storage will not be carried over into the manufactured tobacco products. The insect mortality appears to be caused by heat and vacuum combined, since a very high vacuum alone produced only negligible mortality.—7-1-46.

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Field Experiments with Heat-Generated Aerosols

RANDALL LATTA, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

The development of heat-generated aerosols has been recently reviewed (Latta 1945). As a part of these studies it was desired to explore the possibilities of using aerosols for large-area control of agricultural and forest insects, and among the problems selected as best suited for such a study was the control of larvae of the gypsy moth, *Porthetria dispar* (L.), in forested areas.

Tests were made in heavily infested areas in New England during 1944 and 1945, with various agencies of the Bureau and the State of Connecticut cooperating.[1] The objective of the cooperating agencies was to observe the possibilities of aerosols as a means of controlling gypsy moth infestations. The writer was primarily interested in the behavior of aerosol clouds when applied to forested areas, and the discussion in this paper is based on that phase of the study.

Different generators were used in the two seasons' tests. As discussed previously (Latta 1945), the only aerosol generator available in the spring of 1944 was an army oil-fog generator modified to produce aerosols with particles averaging approximately 2 to 3 microns in diameter. Tests were made with this generator in the Cape Cod area of Massachusetts from May 19 to 22, 1944, when most of the gypsy moth larvae were in the first and second instars.

The aerosols were generated by adding DDT dissolved in cyclohexanone to the oil supply of the generator. In this machine the oil was passed through coils, where it was heated to approximately 950° F., and was dicharged as a vapor. Upon contact with air the vapor condensed into microscopic particles, each of which presumably contained a proportionate amount of the DDT added to the oil. In normal procedure the particles of the oil fogs produced by this generator averaged less than 1 micron in diameter. By discharging the oil vapor into a 30-gallon drum with the head removed, the particles coagulated sufficiently to raise the average diameter to 2 or 3 microns. There may have been some destruction of DDT due to the high temperature. The aerosols were generated from a single point in each instance, and the cloud drifted downwind in the shape of a plume.

A Hochberg-LaMer generator was available for use in 1945, through the courtesy of the Columbia University Laboratory of the National Defense Research Committee. The development of this generator was also discussed previously (Latta 1945). In this machine, oil containing DDT is emulsified with an equal amount of water, and the mixture is passed through a coil and heated to any desired temperature between the boiling point of water and that of the oil. The water phase of the emulsion is vaporized but the oil remains liquid. When discharged through a nozzle by the steam pressure generated in the coil, the oil is broken up into aerosol-sized particles. Almost any desired particle size in the aerosol range can be obtained by manipulation of the temperature and pressure, or by changing the viscosity of the oil. Tests by the inventors indicated no breakdown of DDT at the temperatures normally used. Approximately 15 to 20 gallons of emulsion per hour can be converted into an aerosol in this machine. The aerosols in this instance were applied along the windward front of an experimental plot by mounting the generator on a truck, which moved slowly back and forth across the front of the plot. (Figure 1.)

As could be expected, several applications were unsatisfactory because of poor distribution due to unfavorable atmospheric conditions. Seven applications were satisfactory, three in 1944 and four in 1945. These are briefly outlined as follows:

Treatment A.—May 18, 1944; weather sunny and warm; time 2:30 p.m.; wind 10 MPH or greater above canopy; 8

[1] In 1944 the Division of Forest Insect Investigations and the Division of Gypsy and Brown-tail Moths Control of the Bureau of Entomology and Plant Quarantine assisted in the tests, and in 1945 the Connecticut State Entomologist's Office also assisted. S. F. Potts assisted in the 1944 applications, and Ralph F. Holbrook observed defoliation and feeding during both years, performed tests of repellency, and made records on frass deposit in drop trays, on the numbers of larvae dropping from trees after treatment, and on the mortality of spinning larvae. Other members of these organizations assisted in various aspects of the study.

pounds of DDT applied from a fixed point; terrain rolling, well covered with oaks up to 20 feet high; average particle diameter 1 micron.

Treatment B.—May 20, 1944; weather sunny and warm; time 4 p.m.; wind 10 MPH or greater above canopy; terrain a shallow but narrow valley covered with open growth of oaks up to 20 feet high; 8 pounds of DDT applied from a fixed point; average particle diameter 2 to 3 microns.

Treatment C.—May 22, 1944; weather cloudy, about 65°F., rain 2 hours after application; time 5 p.m.; wind mild, 1 to 2 MPH; terrain hilly, well covered with oaks up to 20 feet high; 8 pounds of DDT applied from a fixed point; average particle diameter 2 to 3 microns.

Treatment D.—May 15, 1945; weather sunny and warm; time 3:15 p.m.; wind 5 to 10 MPH above canopy; terrain level, forested, covered with mixed growth 20 to 30 feet high; 31.5 ounces of DDT applied along a plot frontage of 500 feet; average particle diameter 12 to 20 microns.

Treatment E.—May 23, 1945; weather cool following a sunny and warm day; time 8 p.m., just at dusk; wind none, air drainage down mountainside; terrain mildly rolling area on mountain slope, well covered with tall trees 50 to 60 feet high; 69 ounces of DDT applied along a plot frontage of 500 feet; average particle diameter 12 to 20 microns.

Treatment F.—May 28, 1945; weather cloudy, light rain at intervals; time 2 p.m.; wind 10 MPH; terrain a level forested area, covered with low growth 20 to 30 feet high; 60 ounces of DDT applied along a plot frontage of 660 feet; average particle diameter 12 to 20 microns.

Treatment G.—May 29, 1945; weather sunny and warm; time 2 p.m.; wind 10 MPH above canopy; terrain rolling, on mountainside, well wooded with trees about 50 feet high; 180 ounces of DDT applied along a plot frontage of 500 feet; average particle diameter 12 to 20 microns.

The gypsy moth made an excellent test insect on which to study the behavior of aerosols. For several hours after an application the affected larvae spin down on long threads, and the area covered by an effective concentration of aerosol can be easily delimited by the presence of spinning larvae. The larvae are well distributed vertically, feeding on low underbrush, as well as in foliage clear to the top of the forest canopy. The amount of feeding after the application of an aerosol can be gaged by the use of 3-by-3-foot cloth trays placed under favored host trees. Feeding shows up immediately by the deposit of frass on the trays. Normal larvae feed voraciously on foliage in captivity; therefore tests for residues are comparatively easy to perform. The extent of subsequent defoliation, as well as the occurrence of new egg clusters at the end of the season, also aids in determining migration of larvae into a treated plot. (The female moth oviposits in the immediate vicinity of the pupal case from which she emerged; hence an egg cluster is almost positive evidence of the earlier presence of a grown larva.)

FIG. 1.—Applying an aerosol to a forested area by moving the truck-mounted generator along a woods road.

The behavior of the aerosol clouds as observed visually, and as evidenced by the effect on the population of gypsy moth larvae, is discussed under the following headings.

INFLUENCE OF ATMOSPHERIC CONDITIONS ON APPLICATION TO FORESTED

AREAS.—The application of aerosols to forested areas is somewhat different from that in open terrain. Attempts were made at dawn, throughout the day, and at dusk, under both sunny and overcast conditions, and in the rain. The one thing necessary under all conditions tested was a positive air movement in one direction. With one exception, this was found to exist only when there was a fairly steady wind of 10 MPH or more above the forest canopy. Such a wind above the canopy produced turbulence within the forest, which distributed the aerosols to all heights and yet maintained a general downwind direction of movement. Under

FIG. 2.—Overcoming local turbulence over a forest roadway by use of a high-velocity blower, which carried the aerosol beyond the range of such turbulence.

such conditions rising aerosol clouds were sheared off as they arose above the canopy and were immediately driven back down into the trees. The influence of thermal up-currents existing on sunny days apparently was overcome by this effect.

In winds of lesser velocity above the canopy the air movement in the forests tended to travel in large circles, the direction at one spot changing to all points of the compass within a few minutes.

The one exception encountered was at dusk in an apparently dead calm, when good inversion and an air drainage down a mountainside provided almost ideal conditions for applying an aerosol.

Local turbulence over roadways was also a disadvantage. Regardless of the direction of winds above the canopy, air movement tended to flow down a roadway through the forest. This was overcome in one test by the use of a high-velocity blower (Fig. 2), which carried the aerosol through the forest to a point far enough from the roadway so that movement in one direction was positive.

When aerosols were applied from open terrain along the edge of a forest, turbulence such as existed over roadways was absent, and the air movement satisfactorily carried the aerosols into the forest.

Aerosols applied during light rainfall, as in treatment F, or after heavy rains, were apparently as effective as those applied in dry weather. The residues from aerosols applied when the foliage was very wet, and also where heavy rainfall occurred soon after application, remained repellent throughout most of the season (see later discussion on this subject).

DISTANCE AT WHICH CONTROL WAS EFFECTED.—The effect of an aerosol cloud decreases as the distance from the point of generation increases. For the distance that complete mortality of insects is effected, it can be assumed that more than the needed amount of insecticide has been applied. From that point outward the mortality should decrease in proportion to the increase in distance.

The relation between efficiency and distance was demonstrated in treatment A, where the aerosol was generated at a fixed point and drifted downwind in a plume-shaped cloud. The mortality along a line down the center of the area covered was estimated the day following application. The number of larvae on drop trays and the number remaining on foliage, as compared with untreated areas, were the basis of the estimate.

DISTANCE FROM GENERATOR (FEET)	ESTIMATED MORTALITY (PER CENT)
25	95
50	90
60	85
75	80
100	65
125	60
150	40
200	25
300	15
350	0

As noted previously, the dosages of DDT applied were 8 pounds from a fixed point (treatments A, B, and C), and from

0.063 to 0.36 ounce per front foot on rectangular plots (treatments D, E, F, and G). Complete control was not attained in treatments A, B, and C, except in the immediate vicinity of the point of application. Complete control was attained in treatments D, E, F, and G for distances ranging from 250 to 800 feet.

In treatments D, E, F, and G it had been observed that the aerosol cloud covered an area approximately equal in width to the original front of application. The margins were established by visual observation of the aerosol cloud, and by observation of spinning larvae. In treatment D trays were spotted throughout the area at distances of 10, 25, 50, 60, 100, 120, 150, and 200 feet from the front. In treatments E, F, and G two lines of trays, each about 100 feet in from the established side margins, were placed from front to back of the plots, at 100-foot intervals. The records of frass deposited on these trays and observations of the presence of larvae or evidences of feeding near these stations are given in table 1. Where no frass was deposited until after the 10th day, it was considered that all larvae present had been killed. Feeding after the 10th day, as evidenced by frass on the trays or by actual observation, was considered to be due to larvae migrating into the area from adjacent untreated areas.

It was determined that all larvae spinning down were lethally affected by the aerosol. Various collections of spinning larvae revealed a refusal to feed and complete mortality on the 2nd or 3rd day.

It was not determined whether all larvae in the plots were killed by contact with airborne particles of the aerosol, or whether many of them were killed by contact with a residue of DDT deposited upon bark or foliage. In all tests where drop trays were present during the first few days after an application, larvae continued to drop from trees in large numbers for as long as 8 days. In treatment D

Table 1.—Locations in treated plots where gypsy moths were first present after the application of aerosols.

Treatment	Distance to Last Tray	Time Elapse After Application	Distance at which the Following Were Found			
			Frass on trays	Larvae on foliage	Evidence of feeding	New egg clusters
	Feet	*Days*	*Feet*	*Feet*	*Feet*	*Feet*
D	250	0–10	0	0	0	—
		11–20	150	150	150	—
		21–30	150	150	150	—
		31–40	150	150	150	—
		41–50	100	100	100	—
		51–up	100	100	100	100
E	800	0–10	0	0	0	—
		11–20	0	0	0	—
		21–30	0	0	0	—
		31–40	700	700	700	—
		41–50	700	700	700	—
		51–up	600	600	600	500
F	500	0–10	0	0	0	—
		11–20	500	500	500	—
		21–30	400	400	400	—
		31–40	400	400	400	—
		41–50	400	400	400	—
		51–up	—	—	—	200
G	800	0–10	0	0	0	—
		11–20	0	0	0	—
		21–30	600	600	600	—
		31–40	600	600	600	—
		41–50	600	600	600	—
		51–up	—	—	—	600[1]

[1] One egg cluster found at 200 feet.

many eggs had not yet hatched because of cold weather. The following records of collections on 12 trays indicate that after the third day all the larvae were in the first instar, even though second and third instars predominated in adjacent untreated areas:

DAY AFTER APPLICATION	NUMBER OF LARVAE COLLECTED
1st	1,064
2nd	209
3rd	73
6th	403
7th	122
10th	439

It was concluded that the larvae that dropped during the first 3 days were those present on the foliage when it was treated, and those that dropped on the sixth to tenth days were newly hatched and were killed by crawling up the trunk and over foliage on which there was a DDT deposit. No evidence was found after the other treatments.

In November the numbers of new egg clusters present in 20-foot squares near each station were also recorded (table 1). The presence of a substantial population of gypsy moth larvae throughout the plots and the viability of the general population in contiguous areas were established by pretreatment surveys, records of larvae on untreated foliage amount of defoliation, and records of the egg clusters of the previous and current seasons.

The distances at which control of larvae was attained, with the amount of DDT applied and the average particle size of the aerosol, are summarized in table 2.

Table 2.—Distances at which control of gypsy moth larvae was attained with aerosols.

TREATMENT	DOSAGE PER FRONT FOOT	AVERAGE PARTICLE DIAMETER	DISTANCE OF COMPLETE MORTALITY	FARTHEST DISTANCE OF ANY NOTICEABLE EFFECT
	Ounces	*Microns*	*Feet*	*Feet*
A	128[1]	1	10	350
B	128[1]	2–3	10	1,400
C	128[1]	2–3	160	875[2]
D	0.063	12–20	250	300[2]
E	0.138	12–20	800	900[2]
F	0.09	12–20	500	500[2]
G	0.36	12–20	800	1,000

[1] Applied from a fixed point.
[2] End of infestation.

REPELLENCY OF DEPOSITS FROM AEROSOLS GENERATED IN THE HOCHBERG-LAMER GENERATOR.—DDT applied in dusts and sprays is very toxic to gypsy moth larvae, but other workers have not noticed any repellency of deposits left from such applications, or any reluctance of the larvae to feed on sprayed or dusted foliage. Foliage exposed to aerosols generated in the Hochberg-LaMer generator (treatments D, E, F, and G) was definitely repellent to larvae.

In treatment D foliage collected 25, 50, and 80 feet from the point of origin of the aerosol cloud was fed to lots of larvae on the 3rd, 6th, 10th, 13th, 36th, and 51st days. In no instance would the larvae feed on foliage from the 25-foot station. Not only did they refuse to feed, but they tended to crowd the corners of the feeding trays as far removed from the foliage as possible, and some attempted to escape across the tanglefoot bands, an unprecedented behavior. Foliage collected 50 feet from the point of origin was highly repellent until after the 36th day, but some slight feeding occurred in all trials. Foliage from the 80-foot station had slight repellency through the 13th day. Untreated foliage was consumed voraciously. Foliage from a treatment abandoned because of adverse atmospheric conditions remained repellent to most larvae when fed after various intervals up to 29 days. On the 41st day the foliage was no longer repellent.

In table 1 it will be noted that evidences of feeding, or of frass on trays, were at the most distant part of the plots, where the deposit would be lightest. In all four treatments larvae migrated into the plots from the back margin. In treatment D frass began to appear at 150 and 200 feet on the 13th day, but did not appear on the 100-foot tray until after the 41st day. Also no egg clusters were found closer than 100 feet. In treatment E frass appeared on the 700- and 800-foot trays by the 33rd day, but did not appear on a 600-foot tray until after the 41st day. Only one egg cluster was found inside the 600-foot mark.

In treatment F no frass appeared on any tray until the 15th day, when some appeared at 500 feet. By the 22nd day frass appeared on the 400-foot tray. When egg-cluster counts were made, a few were

found at 300 feet and one at 200 feet. In treatment G no frass was found through the 22nd day, but by the 27th day frass had appeared at 600, 700, and 800 feet. When egg clusters were counted, they were not found any closer than 600 feet, with the one exception at 200 feet. Practically no larvae migrated in from the side margins. The fore part of all plots remained free from larvae throughout the feeding season, even though each was bordered on three sides by moderately heavy infestations, and the distance to the heart of the plots was not too far for larvae to migrate. The apparent conclusion is that the deposition of aerosol was sufficient to remain repellent to, or to cause mortality of, larvae, thus preventing reinfestation during the current season. It has not been determined whether the DDT or some other component of the emulsion was responsible for the repellent action.

APPLICATION OF AEROSOLS TO INDIVIDUAL TREES.—Heat-generated aerosols were also applied in 1945 to a number individual trees along roadsides or in dooryards. Two methods were used—(1) by utilizing the tendency of an aerosol cloud to rise perpendicularly in a dead calm, and (2) by directing the aerosol with a high-velocity air stream produced by a powerful blower.

It was possible to completely envelop even large spreading trees in an aerosol cloud by the first method (figure 3) by making the applications in the calm period often occurring at daybreak. It was necessary to move the truck-mounted generator about under various parts of the tree, which was a disadvantage because of the amount of aerosol needed and the necessity of having access to the entire area under the tree. In four tests the populations were effectively reduced, as evidenced by the numbers of egg clusters in 1945 compared with those in 1944, as follows:

	1944	*1945*
	1,000	44
	200	3
	320	0
	2,214	47
(check)	50	1,004

Individual trees could be quickly and efficiently covered with an aerosol when it was directed by the air stream from a powerful blower, in the manner illustrated in figure 2. In several tests all larvae were killed by small amounts of aerosols so applied.

FIG. 3.—Method of applying an aerosol to an individual tree by employing the tendency of the aerosol cloud to rise perpendicularly in a dead calm.

SUMMARY.—The behavior of aerosol clouds when applied to forested areas was studied in 1944–45 by observing their action on general infestations of larvae of the gypsy moth, *Porthetria dispar* (L.). Two thermal generators were used, a military oil fog generator and a Hochberg-LaMer aerosol generator. Successful applications were performed only when a steady wind of 10 MPH or more existed above the forest canopy, or under good inversion with an eventide air drainage down a mountain slope. Complete mortality was obtained at a depth of 800 feet with as little as 0.138 ounce of DDT per front foot. Aerosols produced in the Hochberg-LaMer generator left a deposit which in some instances remained repellent for the remainder of the feeding season. Methods of applying aerosols to individual roadside or dooryard trees are discussed.

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A Modified Aerosol Formula for Use Against Mosquitoes and Houseflies[1]

A. H. Madden, H. O. Schroeder, E. F. Knipling, and Arthur W. Lindquist, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Workers of the Bureau of Entomology and Plant Quarantine found that pyrethrum in the aerosol formula may be conserved by increasing the amount of sesame oil. Lindquist *et al.* (1945) showed that 0.2 per cent of pyrethrins with the basic DDT aerosol formula (5 per cent of DDT plus 10 per cent of cyclohexanone) produced an excellent spray against both flies and mosquitoes. They have also found that vegetable and motor oils are just as effective as sesame oil in both the pyrethrum and DDT aerosols. The present paper describes a continuation of these studies in which emphasis was placed on a modification of the basic DDT aerosol formula, as well as the pyrethrum formula, for the purpose of increasing effectiveness or improving its physical properties (Lindquist *et al.* 1945, 1946).

As in the preceding work, the tests were conducted against the common malaria mosquito, *Anopheles quadrimaculatus* Say, and the housefly, *Musca domestica* L. No distinctions were made between mortalities of male or female mosquitoes. The same equipment and methods were used; that is, the insects confined in small screen cages were carried around an aerosol-filled room, the mosquitoes for 1 minute and the houseflies for 5 minutes, and then transferred to clean holding cages. In some of the later tests the exposure period for houseflies was reduced from 5 to 2 minutes. In some of the tests aerosols were discharged from special dispensers (McGovran *et al.* 1943) instead of from the standard 1-pound containers. Unless otherwise mentioned, *Freon-12* (dichlorodifluoromethane) was used as the carrier gas.

Effect of Fatty Materials.—Three formulas containing 5 per cent of DDT were prepared in which the content of cyclohexanone was reduced to 6 per cent and 5 per cent of a fatty material—propylene glycol monooleate, propylene glycol monolaurate, or oleic acid—was added. From 5 to 20 tests were conducted with these aerosols against houseflies and mosquitoes at the sublethal dosage of 20 mg. of DDT per 1000 cubic feet. The formula containing propylene glycol monooleate gave no better results against either insect than did the basic DDT formula, but those containing propylene glycol monolaurate and oleic acid gave appreciably greater kills of mosquitoes. In neither case, however, was the increase in effectiveness enough to warrant further consideration of these materials, since there was no marked improvement in the knock-down.

Effect of Wetting Agents.—It appeared possible that a wetting agent might help the particles of insecticide in the aerosol to penetrate the chitin of the insect. Therefore, the effect of adding 2.5 per cent of various wetting agents to the basic DDT formula was studied. The wetting agents used were *Vatsol OT* (dioctyl sodium sulfosuccinate), and *Nopco 1216* (sulfonated sperm oil).

A greater kill of mosquitoes resulted when *Vatsol OT* was added but there was no increase in mortality of houseflies. With the formula containing *Nopco 1216* the mortality of both insects was much less than that obtained with the basic DDT formula.

An attempt to include triethanolamine oleate and *Wetsit* (alkylated aromatic sulfonate) in the series was prevented by the fact that these materials were found to be immiscible in *Freon*.

Effect of Oils.—The results of tests comparing the effectiveness of pyrethrum aerosols (0.4 per cent of pyrethrins) containing 8 per cent of sesame, kerosene, or motor oil (S.A.E. viscosity 10 and 70) are summarized in table 1. The motor oils gave results against mosquitoes comparable with those obtained with sesame oil, but kerosene was definitely less effective. The usual lack of effectiveness of pyrethrum against houseflies is shown, and it is doubtful whether any significance can be placed on the higher kill with the aerosol

[1] This work was conducted under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development to the Bureau of Entomology and Plant Quarantine. The authors are indebted to H. A. Jones for technical advice and assistance on the chemical aspects of the problem, and to J. Beidler, S. A. Webb, and D. Burnett, Jr., for assistance in conducting the tests.

containing kerosene. The results against houseflies in these particular low-dosage tests probably are not significant because total mortalities of 10 per cent or less were obtained. Eagleson (1942) has shown that other oils in pyrethrum fly spray do not increase the toxicity so much as does sesame oil.

A series of tests of the basic DDT aerosol plus 5 per cent of motor oils of different viscosities (table 2) showed that light and heavy oils are equally effective in increasing the toxicity of this aerosol.

Table 1.—Effectiveness against mosquitoes and houseflies of aerosols containing pyrethrum (0.4 per cent of pyrethrins), together with sesame oil, keorsene, or motor oil. Aerosols discharged from a special dispenser at the rate of 1.61 mg. of pyrethrins per 1000 cubic feet. From 380 to 682 insects used in testing each formula.

Oil	Tests	*Anopheles quadrimaculatus*			*Musca domestica*		
		Knock-down in—		Kill in 24 Hours	Knock-down in—		Kill in 24 Hours
		10 Minutes	2 Hours		10 Minutes	2 Hours	
	Number	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*
Sesame oil	9	34	73	68	11	0	8
Kerosene	6	23	22	19	1	0	16
Motor oil:							
S.A.E. 10	6	49	81	60	6	0	10
S.A.E. 70	6	73	85	64	5	0	7

Table 2.—Effect of adding 5 per cent of motor oils of different viscosities to the 5 per cent DDT-10 per cent cyclohexanone aerosol formula. Average of 5 tests, using 267 to 426 insects in each test.

S.A.E. Viscosity of Motor Oil	*Anopheles quadrimaculatus*			*Musca domestica*		
	Knock-down in—		Kill in 24 Hours	Knock-down in—		Kill in 24 Hours
	10 Minutes	2 Hours		10 Minutes	2 Hours	
	Per Cent	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*
No oil	2	6	43	0	3	87
10	1	24	61	0	9	95
30	0	25	67	0	11	96
50	0	21	67	0	18	97
70	1	20	60	0	17	94

To determine what concentration of oil produced the best results, 1, 2, and 5 per cent was added to both the basic DDT formula and the same formula containing pyrethrum in addition. The results are presented in table 3. At the dosage used, increasing the concentration of motor oil from 1 to 5 per cent gave a progressive increase in effectiveness of the basic DDT formula, but not of the DDT-pryethrum formula.

EFFECT OF VARIOUS CONCENTRATIONS OF DDT.—Owing to the possibility of some damage occurring to lacquers and plastics through careless use of DDT aerosol solutions containing 10 per cent of cyclohexanone, a substitute formula appeared desirable. Formulas containing reduced concentrations of DDT with and without reduced concentrations of cyclohexanone were tested. After various combinations and percentages of DDT, pyrethrins, and adjuvants had been tried, a combination which contained 3 per cent of DDT, 5 per cent of cyclohexanone, 5 per cent of motor oil (S.A.E. 30), and 0.2, 0.3, or 0.4 per cent of pyrethrins was formulated. Results of comparative tests with this formula containing each of these three concentrations of pyrethrins and the earlier DDT-cyclohexanone-pyrethrum and pyrethrum-sesame oil formulas, at the sublethal dosage, are presented in table 4.

The new combination with 0.4 per cent of pyrethrins gave the best results against mosquitoes, but all concentrations of pyrethrins gave similar results against houseflies. All the new formulas were less effective than the DDT-cyclohexanone formula against houseflies, apparently owing to the reduction in the concentration of DDT from 5 to 3 per cent. The combinations containing 0.3 and 0.2 per cent of pyrethrins were slightly less effective than the pyrethrum-sesame oil formula against mosquitoes.

At the recommended practical dosage (3 grams of total aerosol per 1000 cubic feet) all the formulas were as effective as

Table 3.—Effect of adding various concentrations of motor oil (S.A.E. 50) to the 5 per cent DDT-10 per cent cyclohexanone aerosol with and without pyrethrum (0.2 per cent of pyrethrins). Dosage of DDT 20 mg. per 1000 cubic feet. Average of 6 tests, with 319 to 478 insects for each formula.

Concentration of Motor Oil in Aerosol	*Anopheles quadrimaculatus*			*Musca domestica*		
	Knock-down in—		Kill in 24 Hours	Knock-down in—		Kill in 24 Hours
	10 Minutes	2 Hours		10 Minutes	2 Hours	
Per Cent	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*
DDT-cyclohexanone:						
1	8	26	33	0	14	66
2	7	31	35	3	28	78
5	4	30	47	0	25	85
DDT-cyclohexanone + pyrethrium:						
1	17	61	45	2	19	70
2	13	47	48	1	15	75
5	14	42	47	1	14	72

Table 4.—Comparative effectiveness against mosquitoes and houseflies of the modified aerosol formula with different percentages of pyrethrins and the basic DDT and basic pyrethrum formulas. From 602 to 1140 insects used in testing each combination. Aerosols discharged at the rate of 12 to 20 mg. of DDT and 0.8 to 1.61 mg. of pyrethrins per 1000 cubic feet.

Aerosol	Tests	*Anopheles quadrimaculatus*			*Musca domestica*		
		Knock-down in—		Kill in 24 Hours	Knock-down in—		Kill in 24 Hours
		10 Minutes	2 Hours		10 Minutes	2 Hours	
	Number	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*
DDT 3%+cyclohexanone 5%+motor oil 5%+pyrethrum:							
Pyrethrins 0.4%	18	45	88	76	10	9	61
Pyrethrins 0.3%	16	26	73	66	4	9	60
Pyrethrins 0.2%	18	19	58	58	4	10	63
DDT 5%+cyclohexanone 10%+pyrethrins 0.2%	12	5	50	56	4	43	90
Pyrethrins 0.4%+sesame oil 8%	18	30	83	68	9	0	8

Table 5.—Comparative tests of 3-per cent DDT, 5-per cent, cyclohexanone, 5-per cent motor oil aerosols with pyrethrum added. Aerosols discharged from the special dispenser at 90 mg. of DDT and 6 to 12 mg. of pyrethrins per 1000 cubic feet. Average of 8 tests with 383 to 540 insects for each formula.

Concentration of Pyrethrins in Aerosol	*Anopheles quadrimaculatus*			*Musca domestica*		
	Knock-down in—		Kill in 24 Hours	Knock-down in—		Kill in 24 Hours
	10 Minutes	2 Hours		10 Minutes	2 Hours	
Per Cent	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*
0.4	96	100	100	97	97	100
.3	90	99	99	96	96	100
.2	91	99.8	100	93	88	99
Check (pyrethrum-sesame oil)	97	91	100	96	54	20

the pyrethrum-sesame oil formula against mosquitoes and much more effective than this formula against houseflies (table 5). The formula containing 0.2 per cent of pyrethrins was practically as effective as the others. However, as an additional margin of safety 0.3 per cent of pyrethrins is preferable. This formula is relatively stable at low temperatures, and yet the concentration of cyclohexanone is not sufficient to cause any concern over potential danger to plastics.

Since these investigations were completed Hazen & Goodhue (1946) have published the results of substituting an aromatic petroleum for the cyclohexanone in this formula. This material produces a satisfactory aerosol, and reduces the corrosive action on the container.

SUMMARY.—Modifications and improvements of the basic DDT aerosol formula (5 per cent of DDT plus 10 per cent of cyclohexanone) for use against common malaria mosquitoes, *Anopheles quadrimaculatus* Say, and houseflies, *Musca domestica* L., are reported.

The addition of fatty materials or of the various wetting agents tested did not materially increase the effectiveness of the basic formula.

Motor oil was found to be just as effective as sesame oil in the pyrethrum aerosol (0.4 per cent of pyrethrins) containing 8 per cent of oil—the results against houseflies being based on low mortalities—and it increased the effectiveness of the DDT formula. The viscosity of the oil had no bearing on the results.

A formula containing 3 per cent of DDT, 5 per cent of cyclohexanone, 5 per cent of motor oil, and 0.3 per cent of pyrethrins was developed which is relatively stable at low temperatures, is safe to use in the presence of plastics, and has the desirable dual effectiveness against both mosquitoes and houseflies.

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CENTRAL PLANT BOARD HOLDS SUMMER MEETING

L. M. GATES

Several members of the Central Plant Board accepted the invitation of the Iowa Nurserymen's Association for the Central Plant Board to meet with them as special guests at Shenandoah, August 6 and 7.

Those in attendance were greatly impressed with the large acreage and excellent condition of the nursery stock grown in and near Shenandoah.

This was the first attempt on the part of the Central Plant Board to hold a summer meeting. It gave an opportunity to inspect nursery stock as a group and to discuss in the field methods of standardizing the procedure of plant inspection in the several states.

In a special meeting of the Plant Board the members present expressed their approval of meeting with the nurserymen and felt it was profitable and worth while and that similar meetings with State Associations of Nurserymen should be made an annual event.

Persistence of Certain DDT Deposits under Field Conditions[1]

F. A. GUNTHER,[2] D. L. LINDGREN,[3] M. I. ELLIOT,[4] and J. P. LADUE[5]

Promising results shown from the use of kerosene sprays containing DDT in control of the California red scale, *Aonidiella aurantii* (Mask.), are due principally to the residual action of the DDT. Initial kill of the adult scale is poor, but residual deposits of the DDT—if sufficiently heavy—will effectively prevent the development of the young scale crawlers (Lindgren & Boyce 1944, Lindgren *et al.*, 1944). Since red scale will produce young over a period of several months, it becomes important to determine the persistence of a given initial deposit of DDT under field conditions.

It is the purpose of the present paper to discuss the results of a field experiment designed to study the effects upon initial spray deposits of (1) degree of purity of the DDT, (2) uses of certain auxiliary solvents, and (3) incorporation into the spray mixture of a petroleum gelling agent (Ebeling 1945) in order to retard penetration of the spray oil, and thus of the DDT dissolved in the oil. In addition, the rates of (4) penetration, (5) reissuance, and (6) weathering and decomposition of two grades of DDT have been determined over a period of three months by both chemical and biological means. This experiment was conducted during the hottest part of the year in order to accentuate the effects of high temperatures upon these factors since it has been shown repeatedly (Sweetman 1945, Gunther & Tow 1946a) that DDT under both field and laboratory conditions may be heat-labile; laboratory studies[6] have indicated also that certain far-ultraviolet radiation may induce a type of photodecomposition of DDT. Unfortunately for this preliminary study, in southern California the period of maximum temperatures usually does not coincide with the period of maximum intensity of sunlight in the far ultraviolet. Sufficient radiation as far down as 2875 Ångstrom units does persist throughout the period studied, however, to indicate that both heat-induced and far ultraviolet-induced decompositions of DDT were probably collectively involved in the present study. Apparently aluminum-ion catalysis was also involved in certain instances of decomposition.

MATERIALS AND METHODS.—Mature orange and lemon trees were sprayed in the conventional manner with the various kerosene emulsion sprays, containing either four or eight grams of technical or chemically pure DDT per 100 milliliters of kerosene, indicated in table 1. In the total of twelve applications, these variations were also extended to include all combinations containing one gram of aluminum stearate and 10 milliliters of tetralin or the latter alone, or, 10 milliliters of *Velsicol AR 60*[7] per 90 milliliters of kerosene.

Table 1.—Spray treatments applied to mature citrus trees. All sprays were used at a final concentration of 3 per cent and with 4 ounces of blood albumin spreader per 100 gallons of spray.

Treatment No.	G. of DDT		Milliliters of			G. of Aluminum Stearate
	Tech.	C.P.	Kerosene	*Tetralin*	*Velsicol AR 60*	
1	4	—	100	—	—	—
2	4	—	100	—	—	1
3	8	—	90	10	—	—
4	8	—	90	10	—	1
5	8	—	90	—	10	—
6	8	—	90	—	10	1
7	—	4	100	—	—	—
8	—	4	100	—	—	1
9	—	8	90	10	—	—
10	—	8	90	10	—	1
11	—	8	90	—	10	—
12	—	8	90	—	10	1

Representative samples of 75 leaves each were collected from the north and south sides of each tree at varying intervals after spraying, and the deposits of DDT thereon were determined immediately by the dehydrohalogenation method (Gunther 1945a and b) of analysis. Eight fruits per treatment from these same trees were also collected at weekly intervals and immediately infested with 200 to 400 red

[1] Presented in part before the American Association of Economic Entomologists in Dallas, Texas, December 6, 1945.
[2] Associate in the Experiment Station.
[3] Associate Entomologist in the Experiment Station.
[4] M. I. Elliot, Principal Laboratory Assistant, assisted in the work.
[5] Principal Laboratory Technician.
[6] Unpublished data by F. A. Gunther.
[7] Essentially a mixture of mono- and di-methyl naphthalenes.

scale crawlers (newly born nymphs) each in the laboratory; the extent of crawler development was determined 3 weeks after infestation. A total of 400 fruits were thus infested and checked for the present study.

In spite of the fact that at the end of the experiment the surface areas of the fruits on the trees were approximately twice as great as at the beginning, with a consequent theoretical halving of the deposit of DDT per unit of fruit surface, it was felt that the resulting bio-assays of DDT deposit could still be interpreted semi-quantitatively. Certain results of the present study, for example, indicated that the final quantity of DDT per unit of surface may be somewhat independent of the quantity originally deposited.

RESULTS AND DISCUSSION.—The residual action of DDT on the prevention of the settling and development of the red scale crawlers was effective generally with all sprays for three weeks. After three weeks a slow decrease in residual action was manifest, especially with those sprays containing the technical grade of DDT. Furthermore, a noticeably longer residual action was obtained with the higher (8 grams per 100 milliliters of kerosene) concentration of DDT regardless of its degree of purity. Chemical analyses of deposits substantiated these observations, as shown in table 2.

Each deposit value is the average of the results from four individual samples, two of which came from the northern halves of the trees, and the other two from the southern halves of the same trees. In table 3 are shown the differenecs existing between initial and final deposits of DDT when the northern halves of the trees are contrasted with the southern, more exposed, halves. In general, there was a slightly greater decrease in the DDT deposit on the southern than on the northern halves of the trees, although in some instances the initial deposit was actually higher on the southern halves.

As may be seen from the data in tables 2 and 3 there were no noteworthy differences in the "persistence" of the two grades of DDT used. Furthermore, the initial deposits of DDT appeared to be comparable on both the northern and the southern halves of a given tree. These findings applied to lemon trees as well as to orange trees, and thus no distinction between the two varieties has been made in the present report.

In order to show the rates of decrease of DDT deposits more clearly, five representative rate curves have been plotted in figure 1. The similarities of contour and slope between these five curves are very striking.

By superimposing the bio-assay values upon the rate curves for the chemical assays, it was found that 12 micrograms of DDT per square centimeter of surface completely prevented the development of the red scale crawlers, whereas fewer than 7 micrograms of DDT per square centimeter had no apparent effect upon either settling or subsequent development. This region of transitional kill has been indi-

Table 2.—Rates of decomposition of 12 spray mixtures containing DDT. (See Table 1 for composition of these spray mixtures.)

TREATMENT No.	MICROGRAMS OF DDT/CM.² OF LEAF SURFACE AFTER								OVERALL % DECREASE IN DDT DEPOSIT
	0 day	1 day	2 days	5 days	13 days	21 days	42 days	86 days	
1	12.3	17.1	17.0	17.2	14.3	15.3	12.2	2.4	81.5
2	17.3	18.1	17.8	16.3	15.8	13.5	10.7	0.8	95.4
3	21.1	26.7	22.9	23.5	20.3	17.9	15.6	2.5	88.2
4	25.5	25.5	25.1	25.2	22.2	17.1	12.9	1.6	93.7
5	29.4	25.5	26.0	26.0	20.9	18.5	11.8	3.6	87.7
6	30.1	23.2	24.5	21.5	18.7	15.7	13.3	1.8	94.0
7	16.0	18.5	20.2	18.2	14.5	13.1	12.4	1.2	92.5
8	20.1	21.7	22.7	20.5	15.5	15.4	13.7	2.1	89.5
9	26.8	28.9	29.2	30.2	25.8	20.8	18.7	4.0	85.0
10	35.8	30.8	31.4	31.0	27.9	27.8	20.1	7.4	79.3
11	31.2	28.3	29.2	26.9	27.3	19.5	17.1	4.7	85.0
12	37.2	34.7	37.3	33.9	31.1	24.7	19.8	5.2	86.0

cated in figure 1 as the "Kill Gradient." This quantitative interpretation is based upon the assumption that the initial deposits of DDT are of approximately the same order of magnitude on both the leaves and the fruits. The validity of this assumption is under investigation.

Table 3.—Differences between northern (shaded) and southern (unshaded) halves of trees treated with DDT with respect to the DDT deposits after 24 hours and after 86 days.

Treatment No.	Portion of Tree	DDT Deposit Micrograms/cm.² of Leaf Surface		% Decrease
		Initial	Final	
1	northern	11.9	3.4	71.4
	southern	12.8	1.5	88.3
2	northern	19.6	0.4	98.0
	southern	15.0	1.2	92.7
3	northern	20.7	3.4	83.6
	southern	21.5	2.4	89.9
4	northern	28.5	1.8	93.7
	southern	19.7	1.4	92.9
5	northern	29.2	4.4	85.0
	southern	29.6	2.8	90.5
6	northern	28.6	1.8	93.7
	southern	31.6	1.8	94.3
7	northern	15.0	1.1	92.6
	southern	17.1	1.1	93.7
8	northern	18.7	2.0	89.3
	southern	20.6	2.1	90.0
9	northern	25.7	3.4	86.8
	southern	27.8	4.6	83.5
10	northern	37.5	8.9	76.3
	southern	34.0	5.8	83.0
11	northern	32.7	7.0	76.5
	southern	29.8	2.4	91.8
12	northern	35.1	6.2	82.4
	southern	39.9	4.1	89.8

It is recognized also that the chemical studies involved leaf surfaces whereas the bio-assays involved fruit surfaces, and that consequently the above interpretations do not take into account increases in surface areas due to normal growth, especially with the fruits.

SUMMARY AND CONCLUSIONS.—Twenty-four hours after spraying, the deposits from those sprays containing only kerosene and DDT showed an increase of DDT up to 40 per cent more than the original deposit which was determined on samples collected at cessation of drip or "run off" of the spray in the usual manner. Those deposits containing *Velsicol AR 60*, on the other hand, showed a decrease of DDT up to 25 per cent within a 24-hour period. After this initial flux, all deposits of DDT decreased steadily at an approximate rate of 0.25 microgram per square centimeter of leaf surface per day for the remaining 85 days of the experiment.

Apparently, then, as the kerosene-DDT spray was applied, much of it penetrated into the leaf tissues almost immediately, carrying the dissolved DDT along with it. But, for the next 24 hours, the kerosene

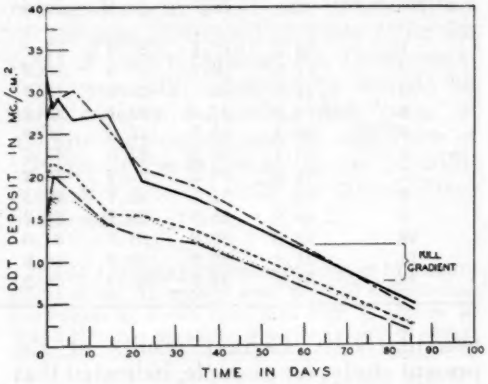

FIG. 1.—Rates of decrease of DDT deposits with time. ..... Treatment 1; ——— treatment 7; - - - - - treatment 8; — — — — treatment 9; ——— treatment 11. See Table 1, for legends.

plus DDT slowly reissued from the leaf to its surface whereupon evaporation of the solvent left a deposit of the DDT. Aluminum stearate largely prevented this initial penetration into the leaf tissues, resulting in a much greater initial deposit of DDT; after 24 hours, however, the surface residue from the spray containing the stearate was very nearly the same as that from the corresponding spray without the stearate.

Tetralin as an auxiliary solvent did not seem to have much effect upon the persistence of the deposit of DDT, nor did aluminum stearate. When the two substances were incorporated into the same spray, however, approximately 14 per cent of the initial deposit was lost within 24

hours. *Velsicol AR 60* as an auxiliary solvent and in combination with DDT resulted in an approximately 16 per cent loss of the initial deposit within 24 hours.

These results suggest that in routine deposit analyses for DDT, the analytical leaf sample should not be stripped for at least 24 hours after spray application when kerosene, aluminum stearate, or tetralin are involved if a correct picture of effective deposit is to be obtained.

Although there were two heavy rains during the latter part of this study, chemical analyses did not indicate any demonstrable effects upon the magnitude of the deposits. After 86 days, however, every treatment showed a loss of from 71 to 95 per cent of the original quantity of DDT deposited. The highest total decreases in DDT residues were shown by those sprays containing aluminum stearate regardless of the presence of an auxiliary solvent. And, in general, the extent of total decomposition for those sprays containing chemically pure DDT was slightly less than for those sprays containing the technical grade of DDT. A distinction between mechanical weathering and chemical decomposition has not been attempted in this report.

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Insect Repellents Used as Skin Treatments by the Armed Forces[1]

B. V. TRAVIS, FRED A. MORTON, and J. H. COCHRAN[2] *U.S.D.A., Agr. Res. Adm. Bureau of Entomology and Plant Quarantine*

At the time of our entry into World War II there were available numerous proprietary insect repellents, many of which had been placed on the market without adequate tests. A project was undertaken at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine in April 1942 to study means of protecting troops from insect bites (Travis & Morton 1946). This involved testing available repellents to determine which were most effective and practical for immediate use by the armed forces. It also involved testing a large number of chemicals in an attempt to locate new and better repellents, and to develop other methods of personal protection from insects. During the period April 1942 to November 1943 about 15,000 laboratory and field tests were conducted. Many of the materials were made up into various mixtures, and about 2500 compounds[3] or mixtures were studied. Comparative data are presented in this paper only for the repellents used by the various military groups—dimethyl phthalate, *Rutgers* 612 (2-ethyl-1,3-hexanediol), Indalone (*n*-butyl mesityl oxide oxalate), and the 6-2-2 mixture (60 per cent dimethyl phthalate, 20 per cent *Rutgers 612*, and 20 per cent *Indalone*) (Travis & Jones 1944). Data are also given to show the relative values of these repellents as compared with citronella and

[1] This work was conducted under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development to the Bureau of Entomology and Plant Quarantine.

[2] The authors wish to acknowledge the assistance of E. F. Knipling, in charge of the Orlando laboratory, and the several members of the Orlando staff, especially A. L. Smith, J. B. Gahan, and J. H. Sawyer. Toxicological testing was done by H. O. Calvery (deceased), of the U. S. Food and Drug Administration.

[3] Some of these compounds were prepared by the Division of Insecticide Investigations; others were obtained from commercial producers.

butyl carbitol acetate. Butyl carbitol acetate was among the earlier repellents developed by Granett (1940) and was employed in the early tests as a standard of comparison.

Several commercial firms had previously investigated repellent materials. The most active in this field was the National Carbon Company. Granett (1940), working at Rutgers University on a project sponsored by this company, developed a standard technique for evaluating different chemicals as mosquito repellents, and furnished many promising materials. In general the laboratory method described by him has been followed.

Granett evaluated most of the materials on himself against different species of *Aëdes* mosquitoes, whereas at Orlando evaluation was based on the results obtained on a group of men against several species of insects. The protection time obtained by Granett with *Aëdes aegypti* (L.) was somewhat longer than that obtained against the same species at Orlando with identical chemicals, but the relative effectiveness of the materials was approximately the same at both laboratories.

LABORATORY TESTS.—Laboratory tests were conducted against the common malaria mosquitoes, *Anopheles quadrimaculatus* Say, the yellow fever mosquito, *Aëdes aegypti*, and the dogfly, or stablefly, *Stomoxys calcitrans* (L.).

The forearms, elbow to wrist, of research subjects were treated with 1 ml. of the material to be tested. The subjects, wearing gloves to protect their hands, exposed their treated arms in screened cages (30 by 30 by 30 inches) containing test insects. Five-minute exposures were made every 20 minutes until a bite was received. The interval between the application of a chemical and the first bite was the repellent time. This figure was used as the criterion of comparison for evaluating the chemicals.

As there is considerable variation among individuals in their response to the same chemical, a series of tests involving a number of research subjects was made to evaluate the repellent time of each material more accurately. Several times a day an untreated arm was exposed in a cage for one-half minute to determine the biting rate of the test insects. In the case of *Aëdes* and *Stomoxys* usually about 2000 insects were maintained in the cages to give biting rates of about 40 or more per half minute, and about 4000 *Anopheles* mosquitoes were maintained to give biting rates of 10 to 20 per 30 seconds. Paired tests were run by applying a different chemical to each arm of the subject, and exposing the arms alternately to the same cage of mosquitoes. This procedure, which was replicated on several subjects over a period of several days or weeks, was followed to reduce variations as much as possible.

FIELD TESTS.—Field tests were conducted against *Aëdes taeniorhynchus* (Wied.), *Stomoxys calcitrans*, *Eusimulium pecuarum* (Riley), *Culicoides* spp., and any other species that could be found in sufficient numbers.

The forearms of the subjects were treated with 1 ml. of the chemical to be tested and, in addition, the legs, knee to ankle, were treated with 1.5 ml. of the same material. A statistical study of the data obtained in the field showed no significant difference in repellent time between material applied on arms and on legs. Accordingly, multiple paired tests were made in which each arm or leg of a group of subjects was treated with one of four repellents—dimethyl phthalate, *Rutgers 612*, *Indalone*, and the 6-2-2 mixture. This method of testing permitted evaluation of the chemicals with a minimum number of tests, as any differences between individuals were common to each of the four repellents being tested.

As a precautionary measure in case there might be selective biting of arms as compared with legs, tests made with each chemical were equally divided between arm and leg treatments. This would be particularly necessary in tests conducted against species of insects that tend to bite either near the ground surface or at higher elevations. The subjects worked in groups of three to five, under the supervision of an entomologist who recorded all bites received. A test was terminated when the third bite was received on any appendage. One man in each group had one leg untreated, and at intervals throughout the day he exposed his leg for a half minute to determine the biting rate. Field tests were usually not conducted when the biting rate was under 20 per half minute; with *Aëdes taeniorhynchus* the biting rate frequently averaged over 100.

Table 1.—Effectiveness of various materials tested as repellents. Orlando, Fla., April 1942 to November 1943.

Material	Laboratory Tests									Field Tests					
	Aëdes aegypti			*Anopheles quadrimaculatus*			*Stomoxys calcitrans*			*Aëdes taeniorhynchus*			*Stomoxys calcitrans*		
	Number of Tests	Protection Minutes		Number of Tests	Protection Minutes		Number of Tests	Protection Minutes		Number of Tests	Protection Minutes		Number of Tests	Protection Minutes	
		Range	Average		Range	Average		Range	Average		Range	Average		Range	Average
Dimethyl phthalate	106	5–521	271	124	13–470	186	20	3–167	47	156	7–396	147	9	9–153	38
Rutgers 612 (2-ethyl-1,3-hexanediol)	118	41–544	368	32	3–255	55	17	11–276	101	96	34–481	275	10	8–69	46
Indalone (*n*-butyl mesityl oxide oxalate)	86	24–413	151	42	2–186	46	21	24–379	171	138	30–382	164	15	77–288	181
6-2-2 mixture	38	138–454	321	41	20–461	278	20	5–436	189	20	40–389	251	—	—	—
Citronella	31	39–157	79	8	7–41	19	—	—	—	15	27–89	56	9	18–106	54
Butyl carbitol acetate	206	34–427	147	73	7–292	111	4	69–143	106	69	39–258	129	10	14–143	74

RESULTS.—The results given in table 1 show that the same test materials varied greatly in their effectiveness when used against different species of insects. In all tests dimethyl phthalate, *Rutgers 612*, and *Indalone* were superior to citronella against mosquitoes, but only *Indalone* and butyl carbitol acetate were superior to citronella when used against *Stomoxys calcitrans*. Dimethyl phthalate was best against *Anopheles quadrimaculatus* (laboratory tests), with an average protection time of nearly 4 hours, and *Rutgers 612* against *Aëdes aegypti* (laboratory) and *A. taeniorhynchus* (field tests), with protection times of 6 and 5 hours, respectively. *Indalone* was best against *Stomoxys calcitrans* (laboratory and field tests), with an average protection time of about 3 hours. Against all species the 6-2-2 mixture gave protection nearly as good as the best individual ingredient, or better. When used against *Anopheles quadrimaculatus* or *Stomoxys calcitrans* it gave much better protection than expected.

All the test materials gave complete protection to the research subjects for 6 to 10 hours against *Eusimulium pecuarum* (the southern buffalo gnat) in Mississippi. Similar protection to domestic animals was obtained with these materials when they were applied as a spray or with a cloth swab at the rate of about 150 ml. per animal.

Dimethyl phthalate, *Rutgers 612*, and *Indalone* prevented biting by moderate populations of *Culicoides* spp. for at least 4 hours. Sometimes, however, these species are very numerous and cause severe annoyance, even when repellents are used, because they land on the face, in the eyes, and in the ears and the mouth.

In the summer of 1943, H. H. Stage, of this Bureau, tested several repellents in northern Canada as a member of the U. S. Army's First Arctic Mosquito Test Expedition. Several species of *Aëdes* were present in large numbers. The average protection time was approximately 2 hours for both dimethyl phthalate and *Rutgers 612*; for *Indalone* it averaged about 1.5 hours. Each of those repellents, and mixtures of them, were considerably better than several commercial repellents containing citronella as the active ingredient.

Since the results obtained at Orlando, as well as those obtained by workers in other areas, showed that the 6-2-2 mixture was effective for a greater range of species than was any one of the chemicals alone, this mixture was recommended for use by the armed forces.

DISCUSSION.—All the species used as test insects, both in the field and in the laboratory, have erratic biting habits. During certain periods they bite readily through repellent materials and at other times they are easily repelled. Because of this characteristic it has been especially difficult to evaluate repellents against *Anopheles quadrimaculatus* and *Stomoxys*

calcitrans. The results obtained with *Aëdes aegypti* and *A. taeniorhynchus* have been the most consistent, and these results can generally be duplicated if the biting rates are comparable and the same test subjects are used. Even with these species, however, very short repellent records have been obtained occasionally.

The duration of repellent action is shortened considerably by perspiration, and varies greatly among individuals; for instance, at least two men are known who receive very little protection from dimethyl phthalate. For these reasons there is usually a wide range in repellent time with all materials tested. The range, however, has been found to be small on the same individual, except in the case of *Anopheles quadrimaculatus*, where erratic results are common. The records obtained on repellent time for a number of test subjects are considered indicative of what might be expected when a large group of subjects use repellent materials.

The technique used for this work was designed as a rapid screening method to evaluate roughly large series of chemicals, and it did not yield the precise data of other methods. It did, however, serve to demonstrate whether chemicals were good or poor repellents. More precise studies were made on the most promising chemicals.

All three repellents have several undesirable features in common. They are solvents of paints and of many plastics, have an oily feeling on the skin, are irritating to mucous membranes, are easily brushed or wiped off, and give very little protection except on surfaces actually covered with a film of repellent.

SUMMARY.—As a result of studies made at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine, four insect repellents were recommended for use by the armed forces. Three of these—dimethyl phthalate, *Rutgers 612* (2-ethyl-1,3-hexanediol), and *Indalone* (*n*-butyl mesityl oxide oxalate)—are individual compounds, and the fourth is a mixture containing 60, 20, and 20 per cent, respectively, of these materials (6-2-2 mixture). Dimethyl phthalate is best against the common malaria mosquito, *Anopheles quadrimaculatus* Say, with an average protection time (interval between application of material and first bite) of nearly 4 hours in the laboratory; *Rutgers 612* is best against the yellow-fever mosquito, *Aëdes aegypti* (L.), in the laboratory and *A. taeniorhynchus* (Wied.) in the field, with 6 and 5 hours' protection, respectively; and *Indalone* is best against the dogfly, or stablefly, *Stomoxys calcitrans* (L.), with an average protection time of about 3 hours both in the laboratory and in the field. All these materials gave protection for 6 to 10 hours against the southern buffalo gnat, *Eusimulium pecuarum* (Riley), when used on man and domestic animals. They also prevented biting by moderate populations of *Culicoides* spp. for at least 4 hours.—6-10-46.

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Hexachlorocyclohexane in the Control of Onion Maggot[1]

W. S. McLeod, *Lecturer in Entomology, The University of Manitoba, Winnipeg, Manitoba, Canada*

In common with all onion growing areas on the continent, the Winnepeg district has suffered severely from attacks of the onion maggot, *Hylemya antiqua* (Meigen). Losses have been especially heavy during the recent cycle of wet seasons and many fields of Dutch sets have been rendered almost worthless in the badly infested areas.

Early in 1945 an experiment to test the effectiveness of various chemical treatments against this pest was designed in co-operation with the Division of Entomology, Dominion Department of Agriculture, Ottawa, Canada. This plan included a total of 29 different treatments and provided for the use of both liquid and dust treatments on the seed, the soil and the growing plants.

Methods.—Liquid seed treatments were applied several days before planting in order to allow thorough drying. Dust treatments were applied to the seed on the morning of seeding day, using sugar syrup as a sticker.

Sprays and dusts for treatment of the soil and the growing plants were first applied either just before oviposition commenced in the field or else during the early stages of oviposition, according to the nature of the insecticide being used. This would be roughly about the time the young plants were an inch high. Sprays and dusts were repeated at weekly intervals until a total of three treatments had been made. Dates of application have not been included in this report because the spring of 1945 was so backward in the Winnipeg area as to make this year's dates almost useless except in relation to each other. For example, seeding took place on May 21st, three weeks to a month later than is customary.

Approximately an acre of Ebenezer onion seed was planted, using two *Planet Junior No. 300* machines, both set at a disc aperture of 22, rows being 12 inches apart. Apertures of 23 and 24 were used where treatment of the seed with various dusts tended to slow the seeding rate. All seed was treated with *Arasan*[2] (tetramethyl thiuramdisulfide 50 per cent) at the rate of 1 pound to 5 pounds of seed for the control of onion smut. Average seeding rate worked out to be about 26 pounds of seed per acre. Commercial practice in this area is to sow from 35 to 40 pounds per acre but part of this increase may be attributed to the use of 8 inch or 10 inch spaces between the rows. It will be noted in table 1 that treatments 1 and 6 were sown at a much reduced rate. This was due to insufficient increase in the disc aperture to compensate for the pelleting of the seed with calomel dust.

Corrosive sublimate solution (Treatment No. 11) was applied with a glass container to which was fastened a rubber tube attached to a 3-foot wand. A glass breather tube through the rubber cork in the bottle allowed the solution to run down the rubber tube by gravity.

All other liquid applications were sprayed on the soil or the plants by means a 2-gallon, compressed-air sprayer. Carefully measured amounts were applied to the three central rows of each plot while surplus spray material was used up on the buffer rows at approximately the same rate.

Dust treatments were applied with a *No. 200 Dobbins Duster*, using a single outlet. The work was done between 6 a.m. and 7:30 a.m. (daylight saving time) and conditions were practically ideal on each of the three days when dusting was performed.

Every treatment was replicated four times in the field. Each plot consisted of five rows, each 25 feet long, separated from adjacent plots by 2 untreated rows and from the next row of plots by a distance of about 12 feet of untreated plants. In each plot the first and fifth rows were used as buffers while data were taken from the three central rows only. For the purpose of counting, a 1-yard strip was marked off in each of the three central rows. As soon as maggot damage appeared, injured plants from this 1-yard strip were pulled and counted. The total number of maggots observed during this

[1] These experiments were conducted by the Department of Entomology, The University of Manitoba, and were financed by a grant from the Manitoba Department of Agriculture.

[2] Supplied by Canadian Industries Limited.

work was recorded. Maggots and damaged plants were in every case removed from the field. At the end of the season the number of healthy plants remaining in the one-year strips was counted. This, added to the number of damaged plants, formed a total from which was calculated the percentage of healthy plants.

It had been hoped to take counts twice a week but weather conditions prevented the completion of this program. In all, six counts were made, the first occurring at the time of the last application of insecticides and the last taking place exactly four weeks later. The first count was completed on only about 100 out of 128 plots. It is thought, however, that the damaged plants which would have shown up in the remainder of the plots at this time were undoubtedly included a week later when the second count was made. It is concluded, therefore, that the totals of all tests are comparable.

STOCK SOLUTIONS.—Stock solutions were prepared as described in the following paragraphs.—

DDT-*Velsicol* stock solution
8 ounces of commercial 100 per cent DDT
2 fluid ounces of *Triton X-100*[1]
Velsicol[2] to make a total of 40 fluid ounces

DDT-acetone stock solution
8 ounces of commercial 100 per cent DDT
4 fluid ounces of *Triton X-100*
Acetone to make a total of 40 fluid ounces

Hexachlorocyclohexane stock solution
8 ounces of crude hexachlorocyclohexane (PC. 982)
4 fluid ounces of *Triton X-100*
Acetone to make a total of 40 fluid ounces

Loro stock solution
6 fluid ounces of *Loro*
4 fluid ounces of *Dupont Spreader Sticker*
26 fluid ounces of water

DESCRIPTION OF THE TREATMENTS.—(1) Calomel seed-treatment. The onion seed was moistened in a 25 per cent sugar solution and mixed with an equal quantity (by weight) of pure calomel. These were stirred together in a glass container. Treatment took place on the morning of seeding day.

(2) Pure DDT seed treatment. The onion seed was moistened in a 25 per cent sugar solution and mixed with half its weight of pure DDT which had been sifted through a piece of ordinary 12-mesh wire mosquoto netting. Seeding was completed the same day.

(3) DDT-*Velsicol* seed treatment. 0.8 ounces of DDT-*Velsicol* stock solution were stirred into 1 gallon of water. The onion seed was soaked in this suspension for 5 minutes and dried thoroughly before planting.

(4) DDT-acetone seed treatment. 0.8 ounces of DDT-acetone stock solution were stirred into 1 gallon of water. The onion seed was soaked in this suspension for 5 minutes and dried thoroughly before planting.

(5) Pure DDT soil treatment. On seeding day a trench about 0.75 inch deep was made in the soil. Pure DDT, previously screened through ordinary 12-mesh wire mosquito netting, was dusted lightly along the bottom of the trench. The onion seed was spread on top of the DDT by hand, covered immediately with soil and packed by tramping.

(6) Calomel seed treatment plus 4 per cent calomel dust. The onion seed was pelletted with an equal weight of pure calomel as in Treatment No. 1 and was planted the same day. As soon as egg-laying commenced in the field, the seedlings and the surrounding soil were dusted with a 4 per cent calomel dust (1 part of pure calomel and 24 parts of talc) at the rate of 1 pound to 200 feet of row. Two additional applications of 4 per cent calomel dust were made at weekly intervals.

(7) Calomel dust, 4 per cent. At seeding time ordinary onion seed, untreated with any insecticidal material, was planted. As soon as egg-laying commenced, the young plants and the surrounding soil were dusted with 4 per cent calomel in talc at the rate of 1 pound to 200 feet of row. Two additional applications were made at weekly intervals.

(8) DDT-acetone spray. As soon as egg-laying commenced, DDT-acetone suspension was applied at the rate of 2 quarts to each 75 feet of row, being careful

[1] Supplied by Rohm & Haas Company.
[2] Supplied through courtesy of Division of Entomology, Department of Agriculture, Ottawa, Canada.

to wet the soil thoroughly along the rows. This suspension was prepared by using 0.8 ounces of the DDT-acetone stock in each gallon of water. This gave a concentration of 0.1% DDT when an Imperial gallon was used. In all, 3 applications were made at weekly intervals.

(9) DDT-*Velsicol* spray. As soon as egg-laying commenced a DDT-*Velsicol* suspension was applied at the rate of 2 quarts to each 75 feet of row, being careful to wet the soil thoroughly along the rows. This suspension contained 0.8 ounces of the DDT-*Velsicol* stock in each Imperial gallon of water, giving a concentration of 0.1% DDT. Three applications were made at weekly intervals.

(10) DDT dust, 3 per cent. As soon as egg-laying commenced, a 3 per cent DDT dust (*Gerasol* A_3) was applied to the soil immediately around the seedlings at the rate of 1 pound of dust to each 200 feet of row. Three applications were made at weekly intervals.

(11) Corrosive sublimate solution. As soon as egg-laying commenced a solution of corrosive sublimate in water 1:1600 was poured on the soil along the row at the rate of 1 gallon to 150 feet of row. Three applications were made at weekly intervals.

(12) Bordeaux-oil emulsion. A few days before oviposition commenced in the field, a bordeaux-lubricating oil emulsion was applied. This was prepared by adding 8 ounces of light lubricating oil to 2 gallons of bordeaux mixture (approximately 4-4-40) and pumping it back into itself until a stable emulsion had been produced. Three applications were made at weekly intervals, using the emulsion at the rate of an Imperial gallon on each 250 feet of row.

(13) AK_{20}. As soon as oviposition commenced, the seedlings and the surrounding soil were sprayed with DDT powder suspension (AK_{20}). This was prepared by mixing 0.8 ounces of powder in 1 gallon of water to give a concentration of 0.1 per cent DDT and was applied 3 times at weekly intervals at the rate of 2 quarts to 75 feet of row.

(14) AK_{20} sweetened. One week before oviposition commenced, the seedlings and the surrounding soil were sprayed with DDT powder suspension (AK_{20}) sweetened. To every gallon of spray mixed according to the directions in Treatment No. 13, 10 ounces of molasses was added. This was applied 3 times at weekly intervals at the rate of 2 quarts to 75 feet of row.

(15) DDT, 3 per cent dust. These plots were treated with 3% DDT dust (*Gerasol* A_3) exactly as in Treatment 10.

(16) Check plot.

(17) Hexachlorocyclohexane, 20 per cent, seed treatment. The onion seed was moistened in a 25 per cent sugar solution and mixed with an equal quantity (by weight) of 20 per cent hexachlorocyclohexane in gypsum. The seed was planted the same day.

(18) Hexachlorocyclohexane suspension seed treatment. A mixture of 1 ounce of hexachlorocyclohexane stock solution in 100 ounces of water was prepared. The onion seed was soaked in this suspension for 5 minutes, and dried thoroughly before planting.

(19) *D-X DDT* emulsion. A few days before oviposition commenced in the field, a *D-X DDT*[1] emulsion was applied to the seedlings and the surrounding soil. One-half ounce of the *D-X DDT* was added to 3.25 gallons of water to give a 1:1040 emulsion. Three applications were made at weekly intervals at the rate of 2 quarts of 75 feet of row. (Preliminary greenhouse experiments indicated that emulsions of 1 to 400 or stronger were detrimental to seedling onions.)

(20) *Para-Scalecide* emulsion. Just before oviposition commenced in the field, a *Para-Scalecide*[1] emulsion was applied to the seedlings and the surrounding soil. Five ounces of *Para-Scalecide* were added to $3\frac{1}{4}$ gallons of water to give a 1:104 emulsion. Three applications were made at weekly intervals, using 2 quarts to 75 feet of row. (In preliminary greenhouse experiments the onion seedlings appeared to tolerate concentrations as high as 1:50.)

(21) *Thanisol* emulsion. Just before oviposition commenced, a 1:3000 *Thanisol*[2] emulsion was applied to the seedlings and the surrounding soil. Three applications were made at weekly intervals, applying the emulsion at the rate of 2 quarts to 75 feet of row. (In preliminary greenhouse experiments it was found that *Thanisol* was somewhat harmful to young onion seedlings even at 1:800, the lowest concentration tested. For safety it was therefore

[1] Supplied by B. G. Pratt Company.
[2] Supplied by Hercules Powder Company.

decided to use 1:3000 in the field since there was not sufficient time to determine the tolerance more accurately.)

(22) Dichlorethyl ether. As soon as oviposition commenced in the field a 1:1040 solution of dichlorethyl ether[1] was sprayed on the plants and the surrounding soil. Three applications were made at weekly intervals, applying the solution at the rate of 2 quarts to 75 feet of row. (Greenhouse experiments indicated that young onion seedlings would tolerate concentrations of dichlorethyl ether as high as 1:400 in water.)

(23) Trichlorethane. As soon as oviposition commenced, a 1:1040 solution of trichlorethane[2] was sprayed on the plants and the surrounding soil. Three applications were made at weekly intervals, applying the solution at the rate of 2 quarts to 75 feet of row. (Greenhouse experiments indicated that a 1:400 solution might be safe on young onion plants.)

(24) Ethyl mercury phosphate. As soon as oviposition commenced a solution of ethyl mercury phosphate was sprayed on the plants and the surrounding soil. The only available source of ethyl mercury phosphate was *Ceresan*,[3] a disinfectant dust for treatment of seed grain, which contains 5 per cent of this material. For the first treatment, 1 ounce of *Ceresan* was dispersed in 3.25 gallons of water to give 1 part of ethyl mercury phosphate in 10,400 parts of water. Two subsequent applications were made at weekly intervals but in each of these the ratio of ethyl mercury phosphate was increased to 1:5200. In every treatment the rate of application was 2 quarts to 75 feet of row. (Greenhouse experiments indicated that these were the strongest solutions that could be used on young onion seedlings without marked detrimental effect.)

(25) Bordeaux-*Volck* emulsion. A few days before oviposition commenced, an emulsion of *Volck*[4] in bordeaux mixture was applied. Three ounces of *Volck* were added to 2 gallons of Bordeaux mixture (approximate 4-4-40) and the mixture was pumped back into itself until a stable emulsion had been produced. Two quarts of emulsion were used on each 125 feet of row and applications were made 3 times at weekly intervals.

(26) A spray of hexachlorocyclohexane was applied just before oviposition commenced in the field. One ounce of the clear liquid from the hexachlorocyclohexane stock solution was used for each 100 ounces of water. This gave a suspension containing 0.2 per cent of the crude product and 0.02 per cent of the gamma isomer of hexachlorocyclohexane. Three applications were made at weekly intervals, care being taken to wet the soil thoroughly on both sides of the row. Applications were made at the rate of 2 quarts to 75 feet of row.

(27) Hexachlorocyclohexane as a spray, sweetened. One week before oviposition commenced, a sweetened spray of hexachlorocyclohexane was applied. The spray was prepared in the same manner as Treatment No. 26 but 10 ounces of molasses was added to every gallon of finished spray. Applications were made 3 times at weekly intervals, using 2 quarts of liquid to each 75 feet of row.

(28) Hexachlorocyclohexane, 5 per cent dust. As soon as oviposition commenced, a 5 per cent dust of hexachlorocyclohexane was applied. This dust was prepared by mixing 10 ounces of 20 per cent hexachlorocyclohexane (sample PC.982Y) with 30 ounces of gypsum. The resulting dust contained 0.5 per cent of the gamma isomer of hexachlorocyclohexane. Applications were made 3 times at weekly intervals at the rate of 2.5 pounds for 500 feet of row.

(29) DDT-sand. As soon as the seedlings pushed through the surface of the ground the rows were treated with sand, the particles of which had been coated with DDT. Two methods of coating were tried. In the first, 1 pound of sand was mixed with 23.8 grams of pure DDT in a ball mill. The results were only partially successful. In the second, 1 pound of sand was soaked in a solution of 23.8 grams of DDT in acetone, the acetone being allowed to evaporate away. The two batches of treated sand were mixed and used to treat 500 feet of row. The treatment was not repeated.

(30) *Loro* emulsion. As soon as oviposition commenced, a *Loro* emulsion was applied. Three ounces of the *Loro* stock solution were mixed with 3.25 gallons of water to give a dilution of 1:1040. Applications were made 3 times at weekly

[1] Supplied by Carbide and Carbon Chemicals Corporation.
[2] Supplied by the Carbide and Carbon Chemicals Corporation.
[3] Manufactured by California Spray-Chemical Corporation.
[4] Manufactured by California Spray Chemicals Corporation. Supplied by Canadian Industries, Ltd.

intervals, at the rate of 2 quarts to 75 feet of row.

(31) Check plot.

(32) Check plot.

RESULTS.—A summary of the results from all treatments may be found in table 1. From this it will be seen that the most successful treatment was No. 6 in which 99.8 per cent of the plants were not damaged by onion maggots. It is entirely possible that the one plant recorded as damaged could have been injured by some

In any consideration of Treatment 6 the results from 1 and 7 should be borne in mind. In Treatment 1 pelleting alone gave 89.1 per cent plants without injury coupled with retarded germination and growth. In Treatment 7 dusting alone gave only 83.9 per cent such plants. This would indicate that a combination of the two treatments would be necessary in order to secure any high degree of control of the maggot.

The small total number of plants in

Table 1.—Total maggots observed and total number of plants damaged by onion maggot, *Hylemy antiqua* (Meigen), in tests with different insecticides in the Winnipeg area in 1945. Each total of maggots and plants damaged based on six counts of 12 1-yard strips.

No.	Treatment	No. of Maggots	Plants Damaged	Total No. of Plants	Percentage Undamaged Plants	Plant Growth
(1)	Calomel seed treatment	10	75	691	89.1	poor
(2)	Pure DDT seed treatment	31	55	1362	96.0	good
(3)	DDT-*Velsicol* seed treatment	486	503	1012	50.3	good
(4)	DDT-acetone seed treatment	475	812	1612	49.6	good
(5)	Pure DDT soil treatment	11	16	1712	99.1	good to excellent
(6)	Calomel seed treatment plus 4 per cent calomel dust	0	1	654	99.8	poor to good
(7)	Calomel dust, 4 per cent	72	225	1397	83.9	good
(8)	DDT-acetone spray	159	215	1204	82.1	good to excellent
(9)	DDT-*Velsicol* spray	45	117	1171	90.0	good
(10)	DDT dust 3 per cent	263	299	1162	74.3	fair to good
(11)	Corrosive sublimate solution	275	323	1341	75.9	fair to good
(12)	Bordeaux-oil emulsion	76	104	1358	93.3	good
(13)	*AK*$_{20}$	203	214	1165	81.6	fair to good
(14)	*AK*$_{20}$ sweetened	105	162	1148	85.9	good
(15)	DDT dust, 3 per cent	331	280	926	69.8	very good to excellent
(16)	Check	451	635	1299	51.1	good
(17)	Seed treatment, hexachlorocyclohexane 20 per cent	—	—	—		seedlings killed
(18)	Hexachlorocyclohexane suspension seed treatment	621	830	1243	33.2	poor to good
(19)	*D-X DDT* emulsion	467	382	1161	67.1	good
(20)	*Para-Scalecide* emulsion	96	139	1145	87.9	good to very good
(21)	*Thanisol* emulsion	221	421	1263	67.0	good
(22)	Dichloroethyl ether	262	409	1126	63.7	good
(23)	Trichlorethane	377	510	1177	56.7	good
(24)	Ethyl mercury phosphate	117	260	1237	79.0	fair
(25)	Bordeaux-*Volck* emulsion	113	138	1539	91.0	good
(26)	Hexachlorocyclohexane spray	8	38	1320	97.1	good
(27)	Hexachlorocyclohexane spray sweetened	18	27	1392	98.1	good
(28)	Hexachlorocyclohexane dust, 5 per cent	9	26	1593	98.4	very good
(29)	DDT-sand	331	363	1024	64.6	good
(30)	*Loro* emulsion	279	311	1207	74.2	slow
(31)	Check	323	382	1257	69.6	good
(32)	Check	308	446	1376	67.6	good

agent other than the onion maggot and that the control was actually 100 per cent in this test. In spite of the excellent control secured, this treatment is considered impractical for two reasons. Firstly, it slowed germination of the onion seed by almost a week and inhibited growth to a noticeable degree. Secondly, its cost is absolutely prohibitive, even for such a valuable crop as Dutch onion sets. There is always the possibility, however, that it might be used by growers of cooking onions who seldom use more than 4 or 5 pounds of seed per acre and whose cost of seed treatment per acre would therefore be very much reduced. There is the further possibility that effective control might be attained at lower dosages.

Treatment 6, and also in No. 1, should be noted. It is probable that this was due largely to an insufficient increase in the disc aperture of the seeder to compensate for the increased diameter of the seeds which had been pelleted with pure calomel. There is still the possibility, however, that, in addition to slowing the germination in these plots, the calomel treatment killed enough seeds to reduce the total number of plants to a marked degree.

The second best treatment, No. 5, was a DDT treatment which gave 99.1 per cent plants not damaged. It had been intended originally to use a 50 per cent micronized DDT dust in this and also in Treatment 2. In spite of our late seeding date in 1945, the necessary material could

not be secured in time for the experiment and it was decided at the last moment to use pure DDT which had been sifted through ordinary wire mosquito netting. The experimental work on the 4 replicates of Treatment 5 was done entirely by hand. This fact alone makes it obvious that the treatment is impractical for commercial use as it now stands. Due to error, these plots were given a much heavier application of the pure DDT than was originally intended and no accurate figures on the amounts used were recorded. It is thought, however, that DDT was probably applied at about the rate of 1 pound to 500 feet of row.

The 3rd, 4th and 5th best treatments were, respectively, Nos. 28, 27, and 26. All of these contained hexachlorocyclohexane in a water suspension or as a dust. The results from these three treatments were truly gratifying. Control of the onion maggot was perfect in all four replicates of each treatment, a total of 12 plots in all, up to the end of the first week following the final application of the insecticides. Only a single maggot had been found in these 12 plots at the end of the second week while during the third and fourth weeks the maggots and damaged plants listed in table 1 were observed. Thus hexachlorocyclohexane in the concentrations used gave almost perfect protection for a period of 2 full weeks after treatments had been discontinued.

The design of this experiment was not such as to permit statistical treatment of the data but the author feels safe in concluding that this new insecticide offers considerable promise for the control of the onion maggot. Not only was it highly satisfactory in three different treatments, each replicated, but a map of the experimental field shows that the plots which were so well protected by the applications of hexachlorocyclohexane were in every case located between plots which were heavily attacked by the onion maggot. There could be no suspicion that these plots had received any benefit which could be traced to a favored position of low infestation.

From the point of view of results secured there would be little choice between the three hexachlorocyclohexane treatments. From a practical point of view, however, the commercial grower would doubtless prefer to use a ready-mixed dust of a suitable concentration. This suggests the need for future research on Treatment 28. Obviously there is a distinct possibility that this treatment may be made more economical by further work on concentrations, rates of application and intervals between applications. It is hoped that this aspect of the problem may be investigated during the summer of 1946.

It might be worth noting that the sixth best treatment, No. 2, was another one involving the use of pure DDT. Briefly it might be said that this treatment, like No. 5, is impractical for commercial use as it now stands but further work with a 50 per cent dust might be profitable.

The next best treatment was No. 12, the old standard bordeaux-lubricating oil emulsion. This yielded a total of 93.3 per cent undamaged plants as compared with 51.1, 69.6 and 67.6 per cent in the checks. While a higher degree of control would be desirable, it would seem that the use of this spray might be well worth while in districts heavily infested with onion maggot, at least until such time as a better insecticide is available for the purpose. Certainly the bordeaux-lubricating oil emulsion was far more successful in these experiments than was the corrosive sublimate solution which yielded only 75.9 per cent plants without injury in Treatment 11.

DISCUSSION.—One of the first things that will be noted in a study of the data is the unsatisfactory control secured with low concentrations of DDT. A concentration of 0.1 per cent DDT as a seed treatment (Nos. 3 and 4) was worthless while the same concentration used as an application to the soil and the seedling plants gave only limited control (Treatments No. 8, 9, 13 and 14). Similarly, a 3 per cent DDT dust (Treatments No. 10 and 15) yielded results which were scarcely better than the checks. On the other hand, the pure DDT used both as a seed treatment (No. 2) and a soil treatment (No. 5) gave very satisfactory results. It is well known, of course, that pure DDT is a difficult material to handle, due to its lumpy, waxy nature. Whether a 50 per cent micronized dust or even a less concentrated material would be effective against this pest remains to be seen but it would seem obvious that the pure product is not suitable for commercial application.

Hexachlorocyclohexane, on the other hand, exceeded all expectations. Samples of the crude product (*PC.982*) and a dust composed of 20 per cent crude hexachlorocyclohexane in gypsum (*PC.982Y*) were received just a few days before seeding time. Very little information was available on its characteristics and uses and there was no time for preliminary experiments. A number of papers have since appeared but those of Slade, Gersdorff & McGovran, and Taylor contain the bulk of the available information.

The compound 1, 2, 3, 4, 5, 6-hexachlorocyclohexane (benzene hexachloride) was first prepared many years ago though its insecticidal properties were discovered only recently. Its chemical formula is $C_6H_6Cl_6$. It is composed of four isomers. Of these, the gamma isomer is the only one which demonstrates extraordinary toxicity toward insects. It usually comprises from 10 to 12 per cent of the crude material.

Hexachlorocyclohexane is insoluble in water. It is, however, soluble in a fairly wide range of other solvents though the author found considerable difficulty in forming either suspensions or emulsions in water. Only the method used in the preparation of the hexachlorocyclohexane stock solution described in this paper was developed in time for field tests during 1945. This method will bring about the solution of all the gamma isomer though portions of some of the other isomers will remain as sediment in the bottom of the bottle of stock solution. Subsequent work has produced other suspensions and emulsions which look promising and it is to be expected that the isomer will prove to be as suitable for spraying purposes as DDT.

The highly satisfactory results secured in Treatments 26, 27, and 28 bear out the claims of British scientists that the gamma isomer is far more toxic to certain insects than is DDT. In these treatments, a spray containing 0.02 per cent (Nos. 26 and 27) and a dust containing 0.5 per cent of the gamma isomer exerted a remarkable degree of control over the onion maggot. Further work will be required to determine the extent to which these percentages may be reduced without a marked reduction in effectiveness.

A note of caution might well be sounded, however, in view of the results secured in Treatment 17. In this test a heavy application of hexachlorocyclohexane killed the seedlings completely. Hence it is conceivable that regular applications of the gamma isomer to the same land over a period of time might result in the accumulation of a concentration of the chemical which would prevent the successful germination of seeds and render the soil useless from an agricultural point of view.

SUMMARY.—A total of twenty-nine different treatments, involving a number of different materials and combinations, were tried in a preliminary experiment on control of the onion maggot, *Hylemya antiqua* (Meigen). A calomel treatment gave almost perfect control but was considered impractical because of its high cost and the retarded growth of the treated plots. One of the DDT treatments was also highly satisfactory but impractical in its present form. Further research would be necessary to determine whether this could be adapted to commercial practices and machinery. Three treatments with hexachlorocyclohexane were almost equally effective and showed great promise of providing a basis for the development of a satisfactory practical control for this pest.—2-11-46.

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Control of Lygus Bugs in Alfalfa Seed Fields[1]

RAY F. SMITH and A. E. MICHELBACHER, *University of California, Berkeley*

Within the past fifteen years there has accumulated sufficient evidence to definitely place lygus bugs[2] as one of the more important factors affecting the yield of seed in alfalfa fields in Western North America (Sorenson 1932, 1939; Stitt, 1940; Carlson, 1941). Many chemicals have been tested and cultural practices such as cultivation, burning, weed control, and uniform cutting recommended, but a satisfactory control of these bugs to the present time has not developed. Sorenson (1942) after 12 years of study in the control of lygus bugs in alfalfa stated that "... other methods than the use of insecticides will have to be employed or developed for the current prevention and control of lygus bugs in alfalfa-seed fields." As has been pointed out by Sorenson (1944) and others this lack of control is due to several factors including (1) the lack of control of the lygus bugs with a wide range of insecticides (2) large scale migration of adults from field to field (3) development of large populations early in the season due in part to wide host range (4) long period over which protection must be afforded to buds, blossoms, and seeds. The first step in the solution of these problems was made when Hills (1944) reported 10 per cent DDT dust in pyrophyllite to be very effective against the adults and nymphs of *Lygus oblineatus* (Say) in cage tests and Stevenson *et al.* (1944) reported 2 per cent DDT in pyrophyllite to be effective against *Lygus* spp. in cage tests. The following year this work was carried into the field by a number of workers. Hills (1945) found one application of 4.5 per cent DDT in pyrophyllite to be an effective insecticide against *Lygus* spp. on sugarbeet seed in small field plots. Michelbacher *et al.* (1945) reported one application of 3 per cent DDT in pyrophyllite at 30 pounds per acre to be very effective in controlling lygus bugs in a 2-acre block in an alfalfa seed field. They suggested that two applications would be necessary in severe infestations. Packard (1945) and Lieberman (1945a, 1945b, 1946) reported upon an experiment conducted in Utah where a 10 per cent DDT in pyrophyllite dust at 27.5 pounds per acre reduced and held lygus bug populations for over 33 days in an alfalfa seed field. The treatment resulted in marked increases in quality and yield of seed. Hills & McKinney (1945) in a series of cage tests found 3 per cent and 5 per cent DDT in pyrophyllite to be effective, but 0.5 per cent DDT in pyrophyllite unsatisfactory against *L. oblineatus*. Loftin (1945) reported upon field and cage tests with DDT dusts against *Lygus oblineatus* and other species on cotton. He found 2 per cent DDT was not as effective as a 4 or 5 per cent DDT dust and that the addition of sulfur caused a quicker kill. Romney *et al.* (1945) found dusts containing 2.5 or 5 per cent DDT and emulsions containing either 0.15 or 0.3 per cent DDT to be effective against *Lygus hesperus* in guayule seed fields. Sorenson & Carlson (1945, 1946) and Sorenson (1946) have reported upon experiments conducted in Utah. In 1944, they compared 10 per cent and 3 per cent DDT dust with 10 per cent sabadilla dust and sulfur-*Pyrocide* dust on small plots (7×7 feet). These treatments were replicated four times at dosages of 30 and 50 pounds per acre and applied at weekly and semi-weekly intervals. The DDT dusts gave highly significant increases in quality and quantity of seed and lygus control above the other treatments in spite of the fact that some of the applications on the DDT plots were omitted. In 1945, no significant differences were obtained between 5 per cent DDT, 3 per cent DDT in sulfur, 20 per cent sabadilla, and an untreated area in a field where the lygus population averaged less than one per sweep during the fruiting period. However, in another field, the same materials were applied twice at 20 pounds per acre to 4-acre blocks. The mean yield of seed on the plots treated with 10 per cent DDT was 6.8 fold greater than on the untreated check plot and the yield on the plot

[1] The authors wish to acknowledge the assistance and advice of E. G. Linsley, J. W. MacSwain, F. R. Platt, N. L. McFarlane and E. O. Eckert during the course of this investigation.

[2] *Lygus hesperus* Knight, *L. elisus* Van Duzee, and *L. oblineatus* (Say) are the common species in alfalfa in the various seed-growing sections of California.

treated with 3 per cent DDT in sulfur was 3.36 times greater than on the check. The lygus count in the check area was 5.16 per sweep.

Lygus bugs are in many fields the most important factor in reducing alfalfa seed yields, but the absence of injurious insects does not insure a satisfactory yield. The physiological condition of the alfalfa plants must be right and the flowers tripped and cross-pollinated by bees before profitable yields are obtained (Linsley 1946a). The lygus bugs feed in both the nymphal and adult stages and cause severe losses by withdrawal of the plant juices, mechanical injury, and perhaps the injection of a toxin. They feed upon and destroy the young growing points (blasting) which results in stunted many-branched plants. They feed upon the ovaries and other succulent parts of the flower causing the flowers to abscise which is known as stripping (Fig. 1) and finally they feed upon the young seeds in the pod causing them to shrivel.

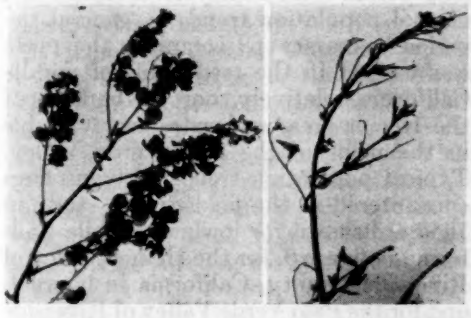

FIG. 1.—*Lygus* injury to alfalfa seed. *Left.* Racemes showing excellent set. *Right.* Racemes severely stripped due to feeding by lygus bugs.

Seasonal cycle in California: The seasonal population trends of lygus bugs have been followed in alfalfa hay fields for a number of years in the northwest portion of the San Joaquin Valley. Data for 1942, a low lygus year in the Tracy-Patterson area, is given in figure 2. The adults come out of winter quarters and move into the alfalfa fields from the latter part of March through April and May. The first nymphs usually appear in May and nymphal population increases at first slowly and then more rapidly to reach peak sometime in June. The adults reach a maximum in June and this continues over into July. The second brood of nymphs appears in early July and continues into August. A third and maybe fourth brood occurs in the late fall. There are apparently three broods a year in this area but the number of generations is probably much greater. The great variation from year to year in the size of these broods is indicated by the

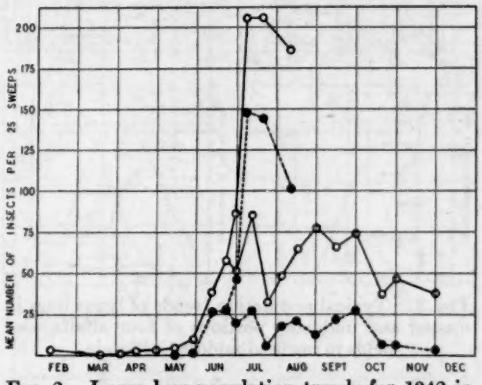

FIG. 2.—Lygus bug population trends for 1942 in alfalfa hay fields (lower branches of curves) and in alfalfa seed fields (upper branches of curves) in the northwest portion of the San Joaquin Valley. Solid line indicates total population; while broken line indicates nymphal population.

data given in table 1. The lygus population in seed fields is not depressed by continued cutting and usually makes but one cycle as indicated in figure 2.

POPULATION TRENDS OF LYGUS BUGS IN SEED FIELDS.—The shape of the population curve during the growth of a seed crop is rather characteristic for most fields. However, the maximum populations vary greatly from field to field. The population of lygus bugs usually start at a rather low level and rise rather rapidly to a peak at full bloom or shortly thereafter. A marked decline in the population then occurs which is associated with competition, action of predators and parasites, and the less favorable condition of the alfalfa. This less favorable condition of the alfalfa is brought about, in part, by the feeding of the lygus bugs and the drying up of the plants as maturity is reached. Where the growing period of the seed crop is very long there may be a second build up of the lygus bug population as new growth starts following the complete blasting of buds by the earlier lygus bug population.

The length of time necessary for the

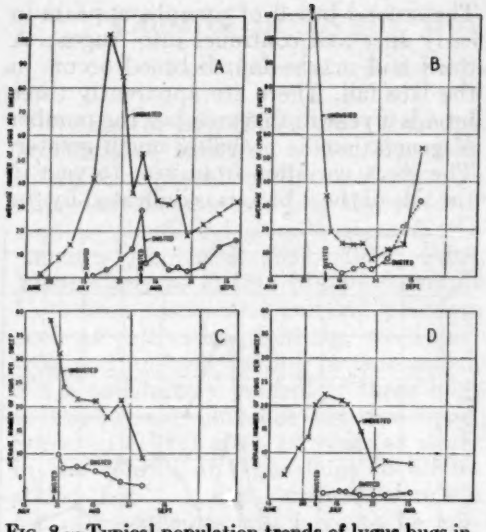

FIG. 3.—Typical population trends of lygus bugs in dusted and undusted portions of four alfalfa seed fields in lowland middle California.

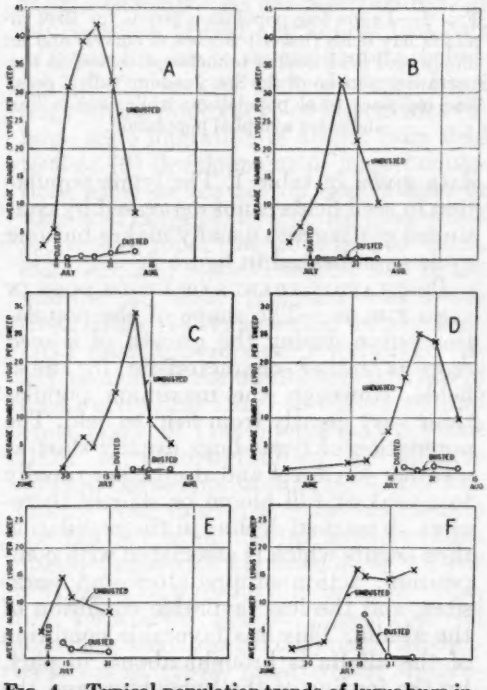

FIG. 4.—Typical population trends of lygus bugs in dusted and undusted portions of six alfalfa seed fields in the Hemet Valley.

population trend of lygus bugs to complete the cycle varies widely. In some fields, it occurs in a period of a few weeks while in others it may take 2 months or more. The length of time is largely dependent upon the conditions under which the alfalfa is grown such as temperature and moisture. If conditions are very dry, the cycle is likely to be of short duration due to the drying up of the alfalfa. High temperature also speeds up the cycle by the acceleration of the development of the lygus bugs and the desiccation of the field. The time necessary for the population to rise and fall is usually longest where a field is irrigated or where the water table is sufficiently high to cause continued growth of the plants. The largest populations are most likely to occur in those fields where a relatively long period is necessary to complete the normal population trend. In general the period necessary to complete the cycle was longest in the seed fields of middle California, relatively short in the fields of the Hemet area, and extremely variable in the fields of the Palo Verde Valley. Typical population trends of lygus bugs encountered in the fields under study in 1945 are shown for lowland middle California in figure 3, for the Hemet Valley of Riverside County, California in figure 4, and for the Palo Verde Valley of Riverside County in figure 5.

Table 1.—Average number of lygus bugs per 25 sweeps in alfalfa hay fields in the San Joaquin Valley of California.

	JUNE BROOD		AUGUST BROOD	
YEAR	Adults	Nymphs	Adults	Nymphs
1941	62	29	77	53
1942	27	26	58	22
1943	67	61	75	23
1944	29	31	67	50

A number of factors complicate the picture of the normal population trend and make general prediction impossible. As mentioned above, in a single area the growth conditions from field to field may be extremely variable. The starting point for the population curve is highly variable due to the great diversity of conditions surrounding fields at the beginning of the growth of a seed crop. Lygus bug populations build up on a large number of wild and cultivated hosts including sugar beets, *Melilotus*, dock, *Astragalus*, cotton, potatoes, beans, and numerous Compositae. The migration of adults from some of these hosts and neighboring alfalfa fields, especially as the latter are cut for hay, is an important factor in influencing the population trend in a field.

EXPERIMENTAL METHODS.—Studies in the control of lygus bugs were conducted in California under a wide variety of climatic conditions in the Sacramento and San Joaquin valleys, at Hemet, and in the Palo Verde Valley. Practically all of the investigations were conducted on a commercial-scale experimental basis. Usually not less than 10 acres were treated in a single block in order to minimize the problems caused by migrating adult lygus bugs. Previous unpublished studies at this station have shown that although small replicated plots are less expensive to conduct, easier to sample, and easier to analyze, they are not practical in the study of control methods due to the constant migration of adults. In this work, the experimental fields were carefully selected for uniformity of stand (sometimes from an airplane) and insect populations. Large check plots (frequently half of the field) were left in each field. Dust mixtures containing from 0.5 to 10 per cent of DDT were used. In lowland middle California the applications were made with ground power-driven dusters and with airplanes. At Hemet, all dusting was done with a ground duster, while in the Palo Verde Valley, all applications were made by airplane. The treated areas were so located as to avoid drift of insecticides over the check areas. The trends of populations of lygus bugs were carefully followed by the sweep method in all fields studied. Each field was surveyed as many times as possible to cover the growth period from pretreatment to the time the crop was nearly mature. Stations were selected throughout the treated and untreated areas of the experimental fields to give an adequate indication of the population. At each station two or five sweeps with an insect net[1] were made and both nymphal and adult lygus bugs counted. The fields were surveyed at intervals not exceeding ten days. Due to the difficulty of making rapid field identification of both adults and nymphs of the species involved in our area, and because the damage caused by the various species indicated by Stitt (1944) was not large, no effort was made to segregate the several species.

EXPERIMENTAL RESULTS.—In 1944 a 2-acre block in a heavily infested seed field near Tracy, California was dusted on July 26 and August 12 with a 3 per cent DDT in pyrophyllite at approximately 28 pounds per acre. Due to untimely rains yield records were not obtained but reduction of lygus bugs under check was approximately 90 per cent after dusting. Estimated yield for the untreated area was less than 150 pounds per acre and over 400 pounds for the treated area.

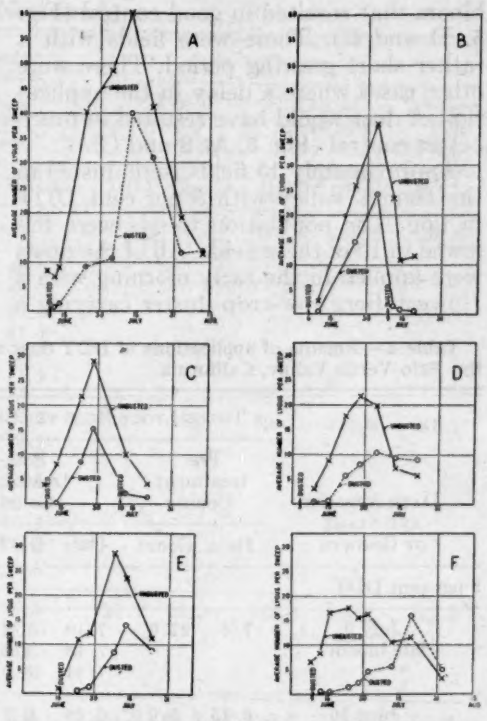

FIG. 5.—Typical population trends of lygus bugs in dusted and undusted portions of six alfalfa-seed fields in the Palo Verde Valley.

The population trends in more than 40 dusted alfalfa-seed fields were followed during the 1945 season in the Palo Verde Valley. All fields were dusted by plane and care was taken to have all applications made under as satisfactory dusting conditions as possible. The results of these experiments are briefly summarized in table 2 and the population trends in six fields are shown in figure 5. In several experimental fields unnecessary second applications of dust were made (Fig. 5, B and C). In these cases, a second dusting would not have been considered had the first application been delayed until 10 lygus could have been taken to a sweep. There were some cases where dusts were applied when the populations were small and before

[1] The frame of the net was an ellipse with a major axis of 15 inches and a minor axis of 13 inches.

bloom that resulted in good control (Fig. 5, D and E). These were fields with a rather short growing period. There were other cases where a delay in the application of dust would have resulted in much better control (Fig. 5, A, B and C).

Approximately 15 fields were dusted in the Hemet Valley with 5 per cent DDT in talc. The population trends were followed in 10 of these fields. All of the dusts were applied in the early morning with a Howery-Berg row-crop duster carrying a fifteen foot canvas drag. The damage done to bedded alfalfa by passing over it with the equipment was negligible. The results of these experiments are summarized in Table 4 and the population trends in six fields are shown in figure 4. In the Hemet Valley the peak populations were reached in the last 2 weeks of July as compared to the Palo Verde Valley where the peak populations were reached near the first of July.

In lowland middle California, the popu-

Table 2.—Results of applications of DDT dust at approximately 30 pounds per acre by airplane in the Palo Verde Valley, California.

Date Applied and Stage of Growth	Total Lygus Bugs per Sweep					Yields				
	Pre-treatment Counts		Post-treatment Counts			Per Cent Cleanout		Lbs. of Clean Seed per Acre		Per Cent Increase in Lbs.
	Date	Count	Date	DDT	Check	DDT	Check	DDT	Check	
3 per cent DDT										
July 9 late bloom	7/2	27.0	7/10	7.2	48.4	—	—	360.4	181.5	98.6
			7/13	4.1	38.1					
			7/21	6.0	22.3					
June 16 prebloom	6/15	1.0	6/23	0.7	10.9	—	—	252.8	171.3	47.6
			6/28	1.4	12.3					
			7/8	8.3	28.4					
			7/13	13.8	23.4					
			7/24	8.8	11.3					
July 10 full bloom	7/3	1.5	7/13	5.6	6.4	24.9	21.2	177.4	133.5	32.9
			7/20	1.9	25.1					
July 10 late bloom	—	—	—	—	—	22.6	25.0	99.4	85.0	16.9
5 per cent DDT										
July 9 late bloom	7/2	27.0	7/10	2.0	48.4	14.6	23.5	428.8	181.5	136.3
			7/13	1.3	38.1					
			7/21	5.5	22.3					
June 9 early bloom	6/8	3.9	6/13	0.2	8.1	10.5	11.9	489.5	302.1	62.0
			6/23	8.6	21.9					
July 10 late bloom			6/28	15.3	28.8					
			7/12	2.1	9.9					
			7/21	1.3	3.9					
June 6 prebloom	—	—	6/10	0.5	2.7	3.6	28.7	479.6	300.5	59.6
			6/25	14.6	25.9					
			7/4	24.1	38.2					
July 9 late bloom			7/11	1.6	23.3					
			7/14	0.9	10.9					
			7/20	0.7	11.7					
June 3 prebloom	—	—	6/9	0.4	3.0	21.7	16.1	500.0	376.7	32.8
			6/15	0.6	8.8					
			6/22	5.6	17.8					
			6/28	8.0	21.8					
			7/5	10.3	19.6					
			7/13	9.3	7.2					
			7/22	9.0	5.6					

Table 2.—(*Continued*)

Date Applied and Stage of Growth	Total Lygus Bugs per Sweep					Yields				
	Pre-treatment Counts		Post-treatment Counts			Per Cent Cleanout		Lbs. of Clean Seed per Acre		Per Cent Increase in Lbs.
	Date	Count	Date	DDT	Check	DDT	Check	DDT	Check	
June 9 early prebloom	6/8	8.5	6/11	0.8	7.0	34.3	40.8	267.2	158.8	68.3
			6/13	1.5	9.1					
			6/24	9.0	40.4					
			7/5	10.7	48.5					
			7/13	39.9	60.0					
			7/22	31.0	41.2					
			8/3	11.8	19.0					
			8/12	12.3	11.9					
June 9 full bloom	6/8	6.6	6/12	0.7	8.3	20.7	18.3	300.1	227.8	31.7
			6/16	0.4	16.4					
			6/24	1.3	17.5					
			6/28	2.2	15.4					
			7/2	4.6	16.4					
			7/12	5.5	10.5					
			7/20	15.7	11.5					
			8/2	5.1	3.4					
July 8 full bloom	7/3	24.6	7/9	1.8	15.5	21.7	22.3	183.4	136.5	34.4
			7/12	2.8	7.9					
			7/20	3.6	19.1					
			8/3	8.3	7.3					
July 10 full bloom	7/3	1.5	7/13	5.6	6.4	11.9	21.2	176.6	133.5	32.3
			7/20	1.8	25.1					
July 10 late bloom	—	—	—	—	—	19.1	23.0	118.4	85.0	39.3
10 per cent DDT										
July 9 late bloom	7/2	27.0	7/10	1.8	48.4	15.8	23.5	385.9	181.5	112.6
			7/13	0.3	38.1					
			7/21	4.8	22.3					
July 10 late bloom	—	—	—	—	—	20.2	23.0	105.9	85.0	24.9

lation trends were followed in seven fields. The population trends in four fields are shown in figure 3. The peak populations occurred in late July and early August. Marked increases in yields resulted in one case where the dust had been applied after the population of lygus had reached its peak (Fig. 3C). It should be noted however that in this field the average population in the untreated areas was over 20 per sweep for nearly a month. The field shown in figure 3A had less than 15 pounds of alfalfa seed per acre in the check area and 411.5 pounds of seed per acre in the treated area, an increase of over 27 fold. The field shown in figure 3C had a yield of 94.7 pounds per acre in the check area and 334.4 pounds per acre in the treated area, an increase of 252 per cent over the check.

Various workers (Lieberman 1945; Sorenson & Carlson 1945; Hills & McKinney 1945) have reported sabadilla dusts to be effective in killing lygus bugs. Five fields in the Palo Verde Valley and one near Tracy were treated in 1945 with sabadilla. The material used in the Palo Verde Valley contained 10 per cent sabadilla seed, while that in the Tracy area contained 20 per cent. The results of these tests are summarized in table 3. The tests with sabadilla were encouraging, but this insecticide did not prove to be as effective as DDT.

TIMING OF DUSTS.—As we have observed conditions in California, lygus

bugs are not likely to cause any material damage until an average of at least five can be collected per sweep of an insect net and severe loss of seed is not likely to result until the population reaches a much higher level. The population trends of lygus bugs for two fields which showed little or no increase in yield are plotted in figure 4E and F. In both cases it should be noted that the peak population of lygus bugs for the undusted portion of the field reached about 15 per sweep. Moreover, on the basis of yield studies in the Tracy area, one would also conclude that when the maximum lygus count is under 15 reasonable yields can be expected. Under some conditions populations of lygus bugs may develop to a point where a complete loss of seed will result (Fig. 3A and B), but this is a population of over fifty lygus bugs per sweep for a considerable period of time. Dusting to control this pest is probably not justified under California conditions unless the number of lygus bugs reach a peak of 15 per sweep. It is rather difficult, if not impossible, to predict such a level in prebloom and the following points should be considered in determining the desirability of treatment: 1) expected increased yield as weighed against cost of treatment; 2) probable size of lygus bug population as affected by vegetative condition of alfalfa, crops grown in adjacent fields, period remaining until harvest, population of beneficial insects (especially pollinating bees), and the effect of the dusting upon these beneficial insects; 3) deposition of alfalfa straw following harvest.

Table 3.—Results of dusting with 10 per cent sabadilla.[1]

District	Pounds Per Acre	Date Applied and Stage of Growth	Total Lygus Bugs Per Sweep				Yields		
							Lbs. of Clean Seed Per Acre		Per Cent Increase in Lbs.
			Date	Treated		Untreated	Treated	Check	
Palo Verde Valley	63	7/8 full bloom	7/3		24.6		169.5	136.5	+33.0
			7/9	1.2		15.5			
			7/12	4.5		7.9			
			7/20	21.3		19.1			
Palo Verde Valley	40	6/16 half bloom	6/15		12.1		260.8	255.7	+ 5.1
			6/23	9.8		23.6			
				5.8		1.6			
Palo Verde Valley	52	6/6 prebloom	6/7	1.8		3.3	251.9	273.5	−21.6
			6/12	12.3		12.0			
			6/25	14.4		22.4			
Palo Verde Valley	30	6/9 early bloom	6/8		6.2		—	—	—
			6/11	5.0		4.5			
Palo Verde Valley	30	6/9 full bloom	6/8		6.1		—	—	—
			6/12	4.2		2.3			
			6/16	8.3		7.0			
			6/25	17.4		9.1			
Tracy	35	7/17 full bloom	7/16		28.2		—	—	+25.0
			7/19	10.8		25.2			
			7/25	6.2		17.7			
			7/31	5.3		8.7			
			8/5	6.4		11.0			
			8/16	7.5		11.0			

[1] A 20 per cent sabadilla dust was used at Tracy.

At the present time we are unable to accurately predict the probable peaks of lygus bug populations. Consequently, with our present knowledge, the population trends must be followed in the individual fields by making rather frequent surveys. Certain generalizations, however, can be made. Large populations are more likely to develop in fields that are in

Table 4.—Results of dusting with 5 per cent DDT in talc by ground machine in the Hemet Valley, California.

Date and Amount Applied Per Acre	Stage of Growth	Total Lygus Bugs per Sweep					Yields		
		Pre-treatment Counts		Post-treatment Counts			Lbs. of Clean Seed Per Acre		Per Cent Increase in Lbs.
		Date	Count	Date	DDT	Check	DDT	Check	
July 19	Full	7/7	6.4	7/25	0.5	28.9	326.2	148.1	120.2
30 lbs.	Bloom	7/10	4.7	7/31	0.4	9.5			
		7/18	14.4	8/8	0.5	5.2			
July 9	Early	7/6	7.0	7/14	1.7	11.0	267.9	149.4	79.2
30 lbs.	Bloom			7/17	1.5	10.7			
				7/31	3.8	4.6			
July 11	Early	7/6	2.7	7/15	0.4	30.9	248.6	147.1	68.7
30 lbs.	Bloom	7/10	7.0	7/20	0.7	39.1			
				7/25	0.5	41.8			
				7/31	1.1	32.3			
				8/9	1.4	8.4			
July 18	Pre-	6/6	0.3	7/21	1.2	2.9	275.8	174.4	58.0
25 lbs.	Bloom	7/17	5.0	7/30	6.3	19.8			
				8/8	10.3	18.6			
July 14	Full	7/6	3.4	7/17	0.4	13.3	180.4	98.7	82.8
40 lbs.	Bloom	7/10	6.1	7/25	0.3	32.4			
				7/31	0.2	21.5			
				8/8	0.2	10.3			
July 17	Early	6/6	0.6	7/20	1.2	17.4	349.8	295.6	18.4
30 lbs.	Bloom	6/29	1.8	7/25	0.5	25.0			
		7/6	2.0	7/31	1.2	23.6			
		7/14	8.8	8/9	0.8	9.9			
July 18	Early	6/6	0.2	7/21	0.4	3.3	181.4	138.6	30.9
25 lbs.	Bloom	7/14	1.5	7/30	2.9	7.9			
		7/17	2.5	8/8	2.0	6.1			
July 19	Late	6/29	1.7	7/21	7.9	14.8	153.8	140.3	9.6
—	Bloom	7/6	3.0	7/30	0.2	14.1			
		7/18	16.0	8/8	0.4	16.0			
July 16	Late	7/6	3.0	7/17	3.1	11.8	88.3	78.9	11.9
30 lbs.	Bloom	7/15	6.4						
July 9	Early	7/6	4.7	7/14	2.7	14.5	210.1	201.7	4.1
30 lbs.	Bloom			7/17	1.2	11.0			
				7/31	1.0	8.2			
July 15	—	7/6	2.1	7/17	0.8	11.7	—	—	—
30 lbs.		7/14	3.7						
July 1	Early	6/30	11.8	7/6	1.8	17.7	—	—	—
30 lbs.	Bloom			7/10	1.2	18.7			
				7/17	1.3	9.9			

a lush, rapidly-growing condition than in those where the growth is poor. Likewise population increases will be greater in those fields where growth of the seed crop is normal as compared to a field that dries up rapidly due to lack of moisture. If the growing period of the crop is long, the development of a large population of lygus bugs is likely. It is in such fields that the timing of the dust application is exceedingly important. If adjacent hay fields containing lygus populations are about to be harvested, the dusting, if at all possible should be delayed until this has occurred in order to avoid the migration of a large number of lygus bugs into the field follow-

ing dusting and to minimize the danger of drift of DDT onto the hay crop. Large migration of adult lygus bugs into a dusted field from a hay field may make it desirable to apply a second application. This situation is well illustrated in figure 3A, where the steep rise in the population of lygus bugs just before the second application of dust was due to a heavy migration of lygus bugs from an adjacent heavily infested hay field that was being cut.

In most cases it would appear best to delay dusting until an average of ten lygus bugs can be collected to the sweep of an insect net. A population of this size is usually not reached until the field is well into bloom. Where a dust is applied too early in the growth of a crop, there is danger that the effective residual action of the DDT will wear off before the seed crop is made, and that much of the seed will be lost due to destructive populations of lygus bugs that subsequently develop. This is almost certain to happen where the period necessary to produce a seed crop is long.

DDT AND POLLINATING BEES.—Ideally the DDT dust should be applied before the alfalfa comes into bloom, for at this time the insecticide will not have any harmful effect upon either wild bees or honeybees. However, in most cases, the ideal time to dust for lygus bug control is after the bloom has started and the bees are in the field. The question of the effect of DDT on bees is not entirely clear as yet. Many workers have reported no losses to bees (Knowlton 1946). Linsley (1946b) and Eckert (1946) reported no losses to colonies, but state there is a suppression of the bee population in the dusted fields for a few days followed by a rise in numbers. In some cases, several days after dusting, the bee population in the dusted area may exceed that found in adjacent undusted areas. This is, no doubt, due to the increased bloom which results from controlling the lygus bugs. Under extreme conditions, the populations of lygus may become so large that all the bloom in the undusted area may be destroyed leaving neither nectar nor pollen for the bees to collect. Where lygus bug populations are large, it can be argued that DDT dusting is beneficial to bees because it increases the honey flow.

Effect of DDT on predators.—Although it was not possible during the 1945 season to make any quantitative studies of the effect of DDT on predators in alfalfa fields, several general observations were made. Ladybird beetles were nearly eliminated in some cases where the dusts were applied. This, however, was not the case with the hemipterous predators and a number, including *Geocoris*, *Nabis ferus* and some Anthocoridae appeared to be less affected by the DDT than was the population of lygus bugs. There were numerous cases where these predators appeared to be noticeably more abundant in the treated than in the check areas. In one case a very large *Geocoris* population developed in the treated area and overflowed into the check where it no doubt was important in reducing the population of lygus bugs. The population trend of lygus bugs for this field is plotted in figure 5F and the overflow of *Geocoris* from the treated area probably accounts for the rather small population and the flattened rather than a sharp peak which occurred in the check as compared to those found in other fields. Although these hemipterous predators are less affected by DDT than lygus bugs at dosages of 30 pounds of 5 per cent DDT dust per acre, it would seem wise to maintain this favorable balance by holding the concentration of DDT in the dust to the absolute minimum that will give satisfactory control of lygus bugs.

RELATIVE EFFECT OF DDT UPON ADULTS AND NYMPHS.—Observations in 1944 indicated that DDT was more effective in killing nymphs of lygus bugs than it was against the adults. These observations were substantiated by general field observations during the past season. Moreover, populations following dusting usually consisted almost wholly of adults, and nymphs were not usually encountered in numbers until a week or more after the treatment was applied.

CARRIERS.—Considerable evidence was obtained during the course of the season's work which indicates that the carrier used influenced the killing action of the dust. A very good kill of lygus bugs was obtained in 1944 with a 3 per cent DDT in pyrophyllite applied at approximately 28 pounds per acre. However, in other tests in the same area in 1945, 3 per cent DDT in talc at approximately the same rate of application did not give a comparable initial kill. Residual action appeared

to be the same. In other tests sulfur appeared to increase the effectiveness of DDT as compared with talc. Some injury to open blossoms occurred where sulfur was used during the blooming period, but in no case did it appear to be of a serious nature. The whole problem of compounding these dusts and the effect of various manufacturing methods is in need of critical investigation. In one test a specially compounded dust that contained only one-half of one per cent of DDT gave surprisingly good control when applied at the rate of 40 pounds per acre. The results of this test are shown in figure 3B.

METHODS OF APPLICATION.—Satisfactory control of lygus was obtained where the dusts were applied either with good ground machines with a canvas drag or by careful airplane dusting. In some cases there was considerable drift and poor control resulted to the windward and excellent control occurred outside the treated plot to the leeward. When airplane applications are made carefully and there is a minimum of air movement, good control will result. Ground machines of the boom-type equipped with an adequate hood or drag gave the most satisfactory results and held the drift to a minimum. On the other hand the heavy ground machines have the disadvantage of crushing bedded alfalfa.

CONCLUSIONS.—DDT is a very satisfactory insecticide for the control of lygus bugs on alfalfa seed crops. It appears to be a safe material but further large scale experimental commercial tests are necessary before unrestricted recommendations can be made. Although it does not appear to be too harmful to wild bees and honeybees, further studies are necessary to prove that this is actually true. The normal lygus bug population trend during the growth of a seed crop is marked by a rather rapid rise of the population to a peak which is reached at about the time the alfalfa is in full bloom. This peak is followed by a more or less abrupt decline. A properly timed dusting should be applied so as to eliminate or suppress the population during the period of most rapid build up. This period of high density of lygus bugs can be best prevented if a dust is applied when the population reaches about 10 lygus bugs (adults and nymphs) per sweep of the insect net. In some cases (Fig. 3A), the dusting is best delayed until even a higher population occurs. There are many fields where control is not justified since the populations frequently do not develop to a point where dusting is economically justified. From our investigations it would appear that exceptionally good control of lygus bugs can be expected when the amount of actual DDT ranges from about 1 to 1.5 pounds per acre. Until more information is obtained, it is believed that best results will be obtained if a 5 per cent DDT dust is applied at 30 pounds per acre. A 3 per cent dust should be applied at from 40 to 50 pounds per acre, and a 4 per cent DDT fused sulfur dust at 30 pounds per acre. It is believed that it may be possible to compound dusts in some manner to increase the effectiveness of DDT so that the actual amount of material needed per acre can be reduced below the figures given above. Improved means of application should also permit reducing the above dosages. Pending a detailed study on the effect of DDT residue on the straw after harvest, it is recommended that straw from fields dusted with DDT not be fed to livestock.—8-3-46.

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Growth of the Sugar-Beet Wireworm on Different Food Plants

F. H. SHIRCK, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[1,2]

Wireworms are known to feed on a wide variety of plants, but there is little published information on how the food plant available to the larva affects its rate of growth. In carrying on life-history studies with various species of wireworms, most investigators have supplied the larvae only with foods favorable to their survival and rapid growth. Lane (1924) used sprouting wheat as food for wireworms reared in salve tins in the laboratory, or in sheet-iron cylinders set in the soil. Bryson (1929) supplied wheat and oats to wireworms reared in tile cages, and Stone (1941) found the growth response of the sugar-beet wireworm, *Limonius californicus* (Mann.) to be favorable on the seeds of corn, wheat, and lima beans. Evans & Gough (1941), in working with larvae of *Agriotes obscurus* (L.), found growth to be more rapid on grains of wheat than on bean seeds or slices of carrot. They also found that the larvae apparently were not able to obtain food from the soil itself, even when its organic matter was increased by adding sewage sludge, farmyard manure, or rotting grass.

PROCEDURE.—In the growth studies of sugar-beet wireworm herein reported, no attempt was made to include all the host plants that might be available to the insect under normal conditions; however, the plants were so chosen that a number of families were represented. Plantings were made in 4- or 6-inch unglazed flowerpots a month or more before the wireworms were released in them, to give the growing plants time to use up all the seed material, making only the roots or other underground parts available for the larvae to feed on. In order to have the larvae small enough so that growth on the host plant would be shown, wireworms that had attained one season's growth in outdoor cages were used. To insure homogeneity, all the larvae taken from the outdoor cages were thoroughly shaken with soil in a covered pail before the required number were withdrawn by chance

[1] In cooperation with the Agricultural Experiment Stations of Washington and Idaho.
[2] This work was done as a part of the wireworm investigations conducted in the Pacific Northwest under the direction of Merton C. Lane.

for inclusion in the tests. To prevent loss of wireworms through cannibalism, only one was placed in each flowerpot. Once a month the lawrvae were removed from the flowerpots and each was placed on moist blotting paper in a 2-ounce salve tin; then it was transferred to a weighing bottle and was weighed on an analytical balance sensitive to 0.1 milligram. After the weights were recorded, the larvae were again placed on moist blotting paper and then transferred to pots containing the same kind of plants that they had previously fed on. The pots were kept in the greenhouse, where mean daily soil temperatures at a depth of 3 inches,in unshaded soil of the same composition as that used in the pots, ranged from 48° to 84°, averaging 68° F. Watering, as required by the various crops to keep the plants growing thriftily, was done by hand. Care was taken not to supply too much water to pots containing soil only, as such pots dried out very slowly.

RESULTS.—The results of a 6-month experiment, which included a number of different field and garden crops, are summarized in table 1. Distinct differences were found in the abilities of the various plants to promote growth of wireworms. Among the cereals, barley, sweet corn, and wheat were satisfactory foods for, wireworms under greenhouse conditions and the growth rate of larvae was not significantly different on these three plants. Oats ranked significantly below barley and sweet corn, but the difference between oats and wheat was not significant. Barley and alfalfa planted together ranked significantly below barley alone and significantly above alfalfa alone.

In tests of carrots and sugar beets different-sized plants were compared. "Large carrots" were old roots that had been potted and caused to resume growth, and "small carrots" were seedlings at least a month old at the beginning of the feeding period. Sugar-beet plants designated as "large" or "small" had 10 to 12 or 4 to 6 leaves per plant, respectively, but in none was there much enlargement of the taproot. The wireworms developed faster on the larger plants of both carrots and sugar beets, but differences were not significant.

FIG. 1.—A block of pots used in greenhouse studies on the relation between food plant and rate of growth of wireworms.

A total of 360 wireworms were used in this experiment, or 20 replicates for each of the flowerpot tests. Only 10 wireworms pupated, the distribution of pupae in the flowerpots being as follows: 4 on barley, 2 on barley and alfalfa, 3 on sweet corn, and 1 on wheat.

Field populations of wireworms have been observed to increase greatly when red clover is grown (Shirck & Lanchester 1936). Evidently sweetclover is also associated with increases in wireworm infestation (U. S. Bureau of Entomology and Plant Quarantine 1937). Alfalfa, on the other hand, does not favor increase. In previous studies by the present author the only increases in alfalfa were in small plots into which adults of the sugar-beet wireworms migrated from adjoining plots

Table 1.—Growth and survival of the sugar-beet wireworm on various plants in the greenhouse. Twin Falls, Idaho, 1943.

Plant	Average Weight at Beginning of Test	Average Gain per Wireworm, by Months						Total Gain per Wireworm[1]	Larvae Surviving at End of Test
		First	Second	Third	Fourth	Fifth	Sixth		
	Mg.	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Per Cent*
Barley	1.3	2.2	0.7	3.7	6.4	9.3	6.5	28.8	30
Peas	2.1	−.3	1.3	3.0	1.9	6.3	13.4	25.6	30
Sweet corn	1.6	1.1	.1	2.6	8.3	6.2	6.4	24.7	35
Wheat	1.1	2.1	0	2.2	5.7	2.2	4.3	16.5	35
Barley and alfalfa	1.6	2.5	0	1.1	2.0	3.0	7.2	15.8	55
Red clover	1.5	.4	.7	.4	2.7	4.0	7.2	15.4	25
Large carrots	2.4	.1	1.8	.9	2.9	4.2	2.0	11.9	25
Large sugar beets	1.3	2.2	−.5	2.0	1.0	1.5	5.1	11.3	40
Cabbage	2.0	−.3	.8	1.4	2.9	3.4	3.7	11.9	10
Oats	1.5	1.2	.1	.3	2.9	2.4	−1.1	5.8	30
Cucumber	1.9	.2	1.0	.1	2.4	1.9	1.8	7.4	25
Beans	1.3	.4	.4	1.2	3.0	1.9	−.5	6.4	25
Onions	1.9	.2	.7	.6	.5	2.0	2.2	6.2	50
Small carrots	2.5	.3	2.1	.2	.9	2.6	−2.7	3.4	10
Small sugar beets	1.3	.5	1.1	−.2	.7	1.0	−.1	3.0	15
Alfalfa	1.4	1.5	−.3	.4	.8	.7	−.2	2.9	15
Lettuce	2.3	−.4	.5	.6	−.4	−.3	.6	.6	15
Soil	1.9	0	.4	.3	−.1	.2	−.5	.3	20

[1] A difference of 10.8 mg. is significant at the 5 per cent level.

of clover or other crops and reinfested the alfalfa plots each year. No satisfactory explanation for this difference between alfalfa and the clovers has been found, but tests reported in this paper show that both red clover and sweetclover are superior to alfalfa as food plants for wireworms.

Since the growth of wireworms was found to be somewhat more rapid on larger plants of sugar beets and carrots than on younger plants of the same varieties (Table 1), it was decided to compare alfalfa, red clover, and sweetclover, using mature plants instead of seedlings. Soil with no food and oats were also included in the test, the data for which are summarized in table 2. The plants were dug up from fields, potted in 6-inch pots, and kept in the greenhouse 6 weeks before the feeding experiments were begun. Each food plant was replicated 30 times, and 1 wireworm was placed in each pot. The wireworms were examined and weighed at monthly intervals for 4 months, the survivors on the three legumes being replaced in the soil with the plants they had been feeding on and the others being placed in pots with fresh oat plants 1 month old. The development of the wireworms was significantly greater on red clover than on alfalfa or in soil containing no plant.

During the experiments summarized in tables 1 and 2, 71 per cent of the wire-

Table 2.—Growth of the sugar-beet wireworm on mature potted plants of legumes, as compared with oats. Twin Falls, Idaho, 1943.

Crop	Average Weight at Beginning of Test	Average Gain in Weight per Wireworms, by Months				Total Gain per Wireworm[1]	Larvae Surviving at End of Test
		First	Second	Third	Fourth		
	Mg.	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Per Cent*
Red clover	1.6	1.3	1.0	6.1	1.5	9.9	37
Sweetclover	1.8	1.6	1.5	2.7	3.5	9.3	40
Alfalfa	2.0	.3	.1	2.6	−.1	2.9	40
Oats	2.2	1.2	.5	2.7	2.0	6.4	20
Soil (check)	2.0	−.5	.3	−.4	−.2	−.8	10

[1] A difference of 6.8 mg. is significant at the 5 per cent level.

worms died. The causes of the heavy mortality were difficult to determine. Few visible indications of disease were encountered. The mortality was evidently associated with nutrition, since it tended to be heavier in the soils containing the poorer foods and in soil with no food.

SUMMARY.—Greenhouse studies to compare several agricultural plants as to their ability to promote growth in wireworms were made at Twin Falls, Idaho. The results presented in this paper show that plants of various sorts vary widely in suitability as food for larvae of the sugar-beet wireworm, *Limonius californicus* (Mann.). The cereals, except oats, ranked first among the plants tested under greenhouse conditions. Barley, barley and alfalfa, sweet corn, and wheat were the only plants tested in which pupation occurred. On alfalfa alone the growth of wireworms was consistently slow. Red clover was a significantly better food plant than alfalfa and ranked above oats. The growth of wireworms feeding on such truck-crop plants as cabbage, sugar beets, cucumbers, onions, and lettuce was poor. The growth of the wireworms was more rapid on older plants than on seedlings of the same varieties.

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LASKER GROUP AWARD TO BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE

A Lasker Group Award was presented to the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, by the American Public Health Association, at the 1946 convention of public health workers held November 12, in Cleveland, Ohio. Engraved on the award, a silver replica of the famous statue "Winged Victory," are the words, "In recognition of distinguished service in the solution of problems involving the health and comfort of the armed forces, with particular reference to insect-borne diseases."

Dr. F. C. Bishopp, Assistant Chief, In Charge of Research, of the Bureau of Entomology and Plant Quarantine, received the Award for the Bureau. Dr. Bishopp is a specialist in the field of medical entomology and he had the over-all direction of the research conducted by the Bureau for the benefit of the armed forces. Three Divisions of the Bureau carried on the research. Entomologists and chemists, working mainly at the Agricultural Research Center at Beltsville, Md., and at the Bureau's laboratory at Orlando, Fla., were responsible for the success of the research program.

The citation which accompanied the award states "Early in the war, the Bureau of Entomology and Plant Quarantine, at the request of the United States Army, undertook the discovery and development of methods to control insects responsible for spreading diseases of particular significance during wartime. Outstanding among these was the search for more effective and practical methods of controlling body lice (typhus) and . . . mosquitoes (malaria, yellow fever, dengue, filariasis, encephalitis, etc.) Specialists skilled in the identification of insects assisted the armed forces by the identification of thousands of . . . insects, mites, and ticks suspected of carrying diseases and by training military personnel. This was part of a program which involved the testing of some 10,000 compounds and the ultimate discovery and adoption of several, including the aerosol bomb, which has been of inestimable value in combatting malaria (and other insect-borne diseases) . . . . The Bureau conducted basic experiments which resulted in the development of dimethyl phthalate and later benzyl benzoate . . . effective in high degree against the mite carriers of scrub typhus . . . undertook studies (on DDT) which were influential in its use in the prevention of epidemic typhus fever among our troops . . . . Equipment was devised by the Bureau for the dispersion of DDT insecticides to meet various field needs . . . . Not the least of the achievements of the Bureau has been . . . its research and control operations against insects of agricultural importance . . . helping to assure an adequate food supply for the armed forces and those behind the lines. The American Public Health Association cites these achievements of the Bureau of Entomology and Plant Quarantine as a notable contribution to the public health."

President Truman, in a letter dated November 7, 1946 regarding the Lasker Awards stated, "We try to take care of our people who are ill, but the greater wisdom would be to bend our greater effort to keep them well by spending money to find not only the cure of disease, but its cause and prevention." It is, of course, more logical and more effective to control disease-carrying insects than to try to cure humans after the insects have caused their diseases.

A Simple Exhaust Aerosol or Spray Generator for Dispersing Insecticide Solutions[1]

R. I. Rice,[2] H. F. Johnstone,[3] and C. W. Kearns,[4,5] *University of Illinois, Urbana*

The importance of mosquito control in war areas and the varied conditions of terrain under which control operations had to be carried out necessitated the development of a number of new devices for dispersing insecticides. Emphasis was placed upon the design of equipment which would be light, compact, easy to operate, free from the possibility of mechanical failure, and capable of efficient dispersion of concentrated spray solutions containing as much as 20 per cent DDT. Data were available which showed that the efficient dispersal of concentrated sprays was dependent upon the ability of the equipment to break up the liquid into small particle sizes, the lower limits of which were determined to be about 10 microns in diameter. Experience has shown that such small particle sizes may be employed only under the most favorable meteorological conditions. Our efforts were therefore directed toward the design of equipment where the mass median diameter of the dispersed solution could be varied through a range of 10 to 200 microns in diameter in order to cope with the effects of varied conditions of terrain and weather.

The equipment was designed primarily for use on the quarter-ton, 4×4 truck, commonly known as the jeep, but with minor modifications it can be adapted for use on other internal combustion engines that are provided with adequate cooling systems.

The principal uses of the equipment up to the present time have been in the dispersal of DDT for the control of flying insects such as flies and mosquitoes in buildings such as dairies, airplane hangars, barracks and auditoriums, and places out of doors such as are found around garbage disposals, livestock pens, public gathering places, forests, swamps and drainage canals. The equipment when used inside buildings is adjusted to produce small drops varying from 5 to 25 microns in diameter while the jeep is driven about in the enclosure. The dosage required to produce desired results under such conditions is about the same as one would use in applying DDT as a liquefied gas aerosol, or about 100 milligrams of DDT per 1000 cubic feet of space. In out-of-door operation the jeep is operated on a front across and upwind from the area being treated. The drop size is regulated to take the maximum advantage of wind drift that is consistent with meteorological and ground conditions in order to extend the area of effective treatment.

In addition to its proven usefulness in control of flies and mosquitoes, it has been used successfully in the control of mosquito larvae in ponds, drainage ditches and swamp areas which were accessible to the jeep. It has also been used successfully to control flies infesting farm lots.

The use of this generator is not limited to application of concentrated solutions of DDT in oil. Other insecticides and solvents including water and emulsions may be applied in a satisfactory manner by changing the flow rate and throttle setting to obtain the desired drop size range. Recently the generator has been used with considerable success for dispersing chlorinated hydrocarbons for the control of grasshoppers, *Melanoplus differentialis*, destroying farm crops. The versatility and the simplicity of the equipment[6] have prompted us to report in detail its construction and operation and to suggest its possible use in the control of other insects where the use of concentrated sprays seems feasible.

Theoretical.—The exhaust generator is a simple venturi nozzle using the gases from an internal combustion engine as the source of energy to break up the liquid. The liquid is injected into the high velocity exhaust gases at the throat of the venturi, and atomization is effected by the shearing forces on the liquid caused by the

[1] This paper is based in part on work done for the Office of Scientific Research and Development under Contract OEMsr-102, with the University of Illinois.
[2] Research Assistant.
[3] Professor of Chemical Engineering.
[4] Associate Professor of Entomology.
[5] Published at the expense of the authors.

[6] Note: Application for patent protection on this equipment has been filed with the U. S. Patent Office and the patent has been assigned to the Board of Trustees of the University of Illinois.

relative velocity between liquid and gas. The average diameter of the droplets decreases as the gas velocity is increased and the rate of liquid flow is decreased.

The gas velocity through a nozzle depends upon the upstream pressure, on the design of the nozzle, and to some extent, on the physical properties of the gas. The velocity through a nozzle attached to the exhaust of an internal combustion engine is limited by the back pressure considered practical for the engine. It is well known that a properly designed venturi throat gives the maximum recovery of the energy required to accelerate the gas through the nozzle and therefore will provide a higher gas velocity than can be obtained with a simple convergent nozzle operating at the same exhaust back pressure.

The extent of atomization of a liquid when it is injected into an air stream has been the subject of several experimental investigations. The most complete published work in this interesting field was by two Japanese engineers, S. Nukiyama and Y. Tanasawa (1938–40), who, on the basis of a large number of experiments, were able to derive two empirical correlations on the drop size distribution and performance of pneumatic nozzles. These have served as a basis for a more extensive study in this laboratory in which it was found that the same methods of correlation could be applied to exhaust atomizers and, in a limited way, to hydraulic nozzles. The important factors influencing the degree of atomization are: (a) the relative velocity of the gas at the point of injection of the liquid, (b) the physical properties of the liquid, including surface tension, viscosity and density, and (c) the relative quantity of gas expressed by the ratio: volume of gas to the volume of liquid. Over a limited range of these variables the following empirical equation represents the degree of atomization:

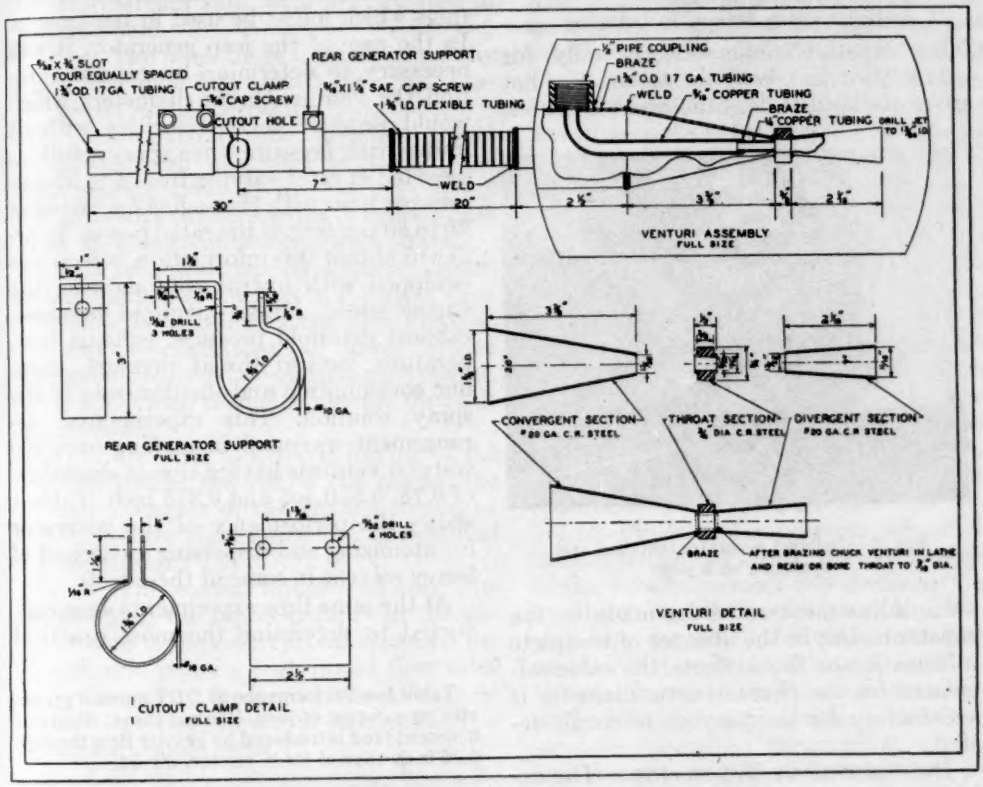

FIG. 1.—Details of construction of the exhaust generator.

$$D_0=\frac{585\sqrt{\sigma}}{v\sqrt{\rho}}+597\left(\frac{\mu}{\sqrt{\sigma\rho}}\right)^{0.45}\left(\frac{1000Q_L}{Q_A}\right)^{1.5}$$

where

D_0 = the characteristic drop diameter expressed as the diameter in microns of a single drop with the same ratio of surface to volume as a representative sample of the drops in the spray.

v = relative velocity between gas and liquid at the point of injection of the liquid into the gas in meters/second.

Q_A/Q_L = volume flow rate of gas/volume flow rate of liquid.

ρ = liquid density in g./ml.

μ = liquid viscosity in poises.

σ = liquid surface tension, in dynes/cm.

This equation holds strictly only for atomization in a cold air stream. For hot gases of different densities and viscosities,

FIG. 2.—Exhaust generator installed and operating on a jeep.

some adjustment must be made in the constants, but in the absence of complete information on these effects, the value calculated for the characteristic diameter is satisfactory for the purpose of rough design.

DESCRIPTION OF GENERATOR.—The exhaust generator as finally adopted for the jeep is as simple a device as could be made for dispersing insecticide solutions from a motorized unit. A detailed drawing is shown in figure 1. It includes an insecticide reservoir, a control valve with indicating dial, a length of flexible hose, a simple clamp cutout, and a sheet metal venturi nozzle which is clamped on the exhaust pipe after the muffler has been removed. The venturi is mounted on the flexible tubing extension, which permits the generator to be pointed at any angle as required in different types of treatments. In the photograph, figure 2, the equipment is shown installed and in operation.

EXPERIMENTAL.—The venturi exhaust principle has been successfully used by us for dispersing sprays and aerosols from aircraft and thus much of the usual preliminary experimentation was eliminated through information previously obtained. It was known that the exhaust gas velocity in the throat of the venturi should vary from 800 to 1500 feet per second at the minimum and maximum power settings which might be used in treatments. In the case of the jeep generator, it was necessary to determine by experimentation the venturi throat diameters which would produce these velocities without undue back pressure when spray solutions were fed at rates varying from 5 to 50 gallons per hour with the engine operating at 20 to 50 per cent of the rated power. In order to obtain this information, a jeep was equipped with instruments showing the engine speed, intake manifold pressure, exhaust manifold pressure, exhaust temperature, venturi throat pressure, gasoline consumption and the flow rate of the spray solution. This experimental arrangement was used in making over 100 tests on venturis having throad diameters of 0.75, 0.5, 0.465 and 0.375 inch. Table 1 shows the performance of the generator for atomizing and dispersing an aerosol of heavy solvent in some of these tests.

At the same time experiments were conducted to determine the most practical method of injecting the spray liquid into the venturi throat. Five types of liquid injection were studied:

Table 1.—Performance of DDT aerosol generator on exhaust of jeep. Venturi throat diameter 0.5 inch; feed introduced by gravity flow through 0.20 inch coaxial jet in venturi throat.

Engine Speed, R.P.M.	Venturi Exit Dia., in.	Exhaust Pressure, Inches Mercury		Oil Flow, G.P.H.	Mass Median Diameter of Aerosol, Microns
		Dry	Spraying		
2980	1.5	1.8	2.1	1.4	15
3275	1.5	3.0	3.5	2.7	15
3275	0.80	3.2	4.1	6.1	45
3250	0.84	4.9	6.1	5.3	40
2800	0.84	2.9	3.9	3.7	35
2800	0.80	3.3	4.3	7.2	45
3275	0.80	5.5	6.9	7.7	20
2800	0.72	3.4	4.6	7.0	50
3250	0.72	5.9	7.1	7.7	25
2800	0.64	3.6	5.7	7.6	35
3250	0.64	6.7	8.2	7.0	15
2800	0.55	4.5	5.7	6.0	35
3250	0.55	8.3	9.7	4.8	10

1. a hollow cone spray nozzle with pump.
2. a sharp-edge orifice in the wall of the venturi throat with gravity feed of the liquid.
3. a tube extending radially into the throat of the venturi with liquid injected into the center of the throat through a hole in the tube wall on the downstream side, with gravity feed of the liquid.
4. two open tubes extending radially 0.0625 inch into throat with liquid injected radially, gravity feed.
5. a coaxial tube injecting liquid downstream and parallel to the gas stream, gravity feed.

After an extensive series of experiments the following conclusions were drawn:

1. A venturi having a throat diameter of 0.4375 inch is the largest that would be suitable for the jeep. For continuous operations at lower engine speeds, to avoid overheating the engine, a 0.375 inch diameter venturi throat is suitable.
2. In order to avoid dribbling of the liquid from the end of the nozzle, the exit diameter of the venturi should be no greater than twice the diameter of the throat.
3. The coaxial liquid feed tube discharging the liquid parallel to the gas stream is the best type of injection because it permits high liquid flow rates with gravity feed even when the pressure at the throat of the venturi is above atmospheric.
4. A simple clamp cutout should be provided and opened when the jeep is not being used for insecticide application.

The choice between the two sizes of venturis with throat sections 0.4375 or 0.375 inch in diameter should be made largely on the basis of the mechanical condition of the engine. An engine in good condition with no tendency to overheat will handle a 0.4375 inch diameter venturi to full advantage if run at a speed corresponding to at least 6 miles per hour in low gear, low range. This minimum setting is equivalent to about 2200 r.p.m., or 38 m.p.h. in high gear, high range. With the 0.375 inch diameter venturi, the minimum operating speed is 5 m.p.h. in low gear, low range. This corresponds to an engine speed of 1900 r.p.m. The reduced speed will decrease engine wear but will also decrease the capacity of the generator to atomize the liquid. Better results may be expected with either installation if the engine is operated at power settings above the minimum conditions stated.

In operation there are two controls on the equipment as described which may be used to provide the drop sizes needed for most efficient dispersal of the insecticide solution: (1) the engine throttle, and (2) the valve on the insecticide line. For the largest drop sizes the valve on the solution line is opened so that the flow of solution is between 30 and 50 gallons per hour. The throttle is advanced until dripping at the exit of the venturi just ceases. Further advance of the throttle will decrease the drop size of the spray. For the finest mists, or aerosols, the calibrated indicating dial on the valve on the insecticide line should be set to give 5 to 10 gallons per hour and the throttle advanced until the white smoke cloud just breaks away from the exit of the venturi. This setting produces the finest mist or aerosol obtainable. The mass median diameter of the drops under these conditions is 10 to 15 microns.

USE OF JEEP GENERATOR.—In early tests at Orlando, Florida, the effectiveness of the exhaust aerosol was demonstrated by dispersing DDT solution at the doorway of a large 350,000 cubic foot gymnasium. A dosage of 100 mg. of DDT per 1000 cu. ft. was used. This required only a single blast from the exhaust lasting 15 seconds. Complete penetration of the building was demonstrated by 100 per cent kill of flies and mosquitoes in stationary and waved cages exposed for 5 minutes in the balconies and remote corners of the building.

This test was followed by use of the jeep unit for the control of mosquitoes at various military installations in Florida. At one airfield, the unit was used for treating hangars, guard houses and outdoor work racks. One or two treatments were applied each night for these areas to provide complete relief of personnel from annoyance by mosquitoes. Indoor dispersal was usually carried on until the aerosol could be seen leaving through the windows and ventilators. Community picnic grounds, outdoor theaters, mess halls and post exchanges were also treated.

The exhaust generator was tested extensively on the Pacific Islands near the end of the war, and has been used with success since the war, both in this country and abroad, for the control of flies and mosquitoes in a variety of situations. A dispersal rate of 5 gallons per hour is usually recommended for 5 per cent solutions of DDT in kerosene. Concentrated solutions

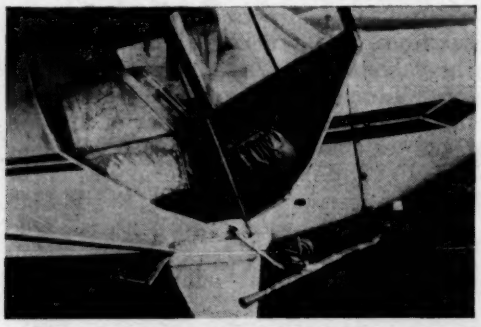

FIG. 3.—Exhaust generator and spray reservoir installed on *Taylorcraft* airplane.

containing 20 per cent DDT in aromatic solvents have been used at lower dispersal rates. In treating dairy barns and lots, twice weekly applications for 2 weeks, followed by applications as often as necessary, probably not more than once every 2 weeks, keep the fly population down to a tolerably low level. For outdoor use in open areas the aerosol is effective when carried by a moderately strong wind, but such conditions require higher dosages than a light breeze which is most favorable for dispersal. For penetration through heavy vegetation, dispersal in a strong breeze appears to be best.

Tests were also made with the jeep unit for larvicide application to roadside marshes, ponds, and pools around buildings. In order to obtain sufficient surface deposits, the coarser sprays were found to be more satisfactory for general larvicidal purposes than the aerosol, especially if there was a definite wind to carry the droplets. Satisfactory results may be expected 100 to 200 feet downwind under almost any condition of operation.

The jeep unit has recently been successfully used as a substitute for conventional sprayers in the control of the grasshoppers *Melanoplus differentialis* and *M. femur-rubrum* attacking various types of crops in Illinois. Concentrated emulsions and solutions were applied in 20 to 30 foot swaths at the rate of 3 gallons per acre. In this work the flow rate and power setting were adjusted to produce a spray with a mass median diameter of approximately 50 microns. The jeep was driven at 3 miles per hour.

INSTALLATION ON OTHER MOTOR VEHICLES.—The generator may also be used on other types of motor vehicles powered by internal combustion engines, provided that the dimensions of the venturi are adjusted to the rate of flow of the exhaust gases and the cooling system is adequate at the high engine speeds necessary for applying the insecticides. Use of the generator on modern cars and light trucks has not been too successful because of overheating of the engine but several units have been installed on heavy trucks and on small boat engines and used without difficulty in this respect. Table 2 shows the dimensions of the venturi recommended for gasoline engines of various horsepowers.

INSTALLATIONS ON AIRPLANES.—Successful application of the venturi atomizer has also been made to the dispersal of insecticide solutions from light aircraft. Figure 3 shows the equipment installed on a *Taylorcraft* plane with a 65 h.p. *Continental* engine. A 24-gallon removable seat tank was used for storage of the insecticide solution. The venturi had a 0.875 inch diameter throat which produced a back pressure on the exhaust of 5.5 inches of

Table 2.—Dimensions of exhaust aerosol generators for various size engines.

Rated Engine, H.P.	Gasoline Consumption, gal./hr.	Dimensions of Generator			Size of Feed Line, Dia., in.	Liquid Rates gal./hr.	
		Throat, Dia., in.	Exit, Dia., in.	Feed Jet, Dia., in.		Aerosol	Spray
40– 60	1 to 3	0.437	0.687	0.2	0.5	8–15	30–60
60– 90	3 to 4	0.625	0.875	0.25	0.5	15–20	60–80
90–120	4 to 6	0.687	1.25	0.31	0.75	20–25	80–100
120–175	6 to 10	0.937	3.75	0.375	0.75	25–35	100–150

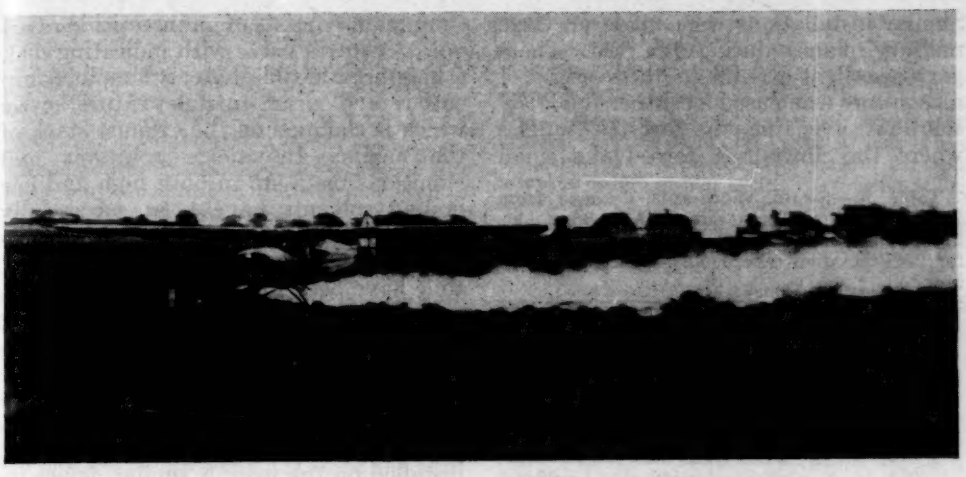

FIG. 4.—Exhaust generator in operation on plane.

mercury at full power and decreased the top speed of the plane about 5 m.p.h. A cruising speed of 90 m.p.h. with the engine at 2100 r.p.m. was found to be most practical for spraying. The back pressure on the exhaust while spraying was 4.4 inches of mercury. For air temperatures below 80°F. the temperature of the lubricating oil in the engine rose only slightly above normal when the plane was used for several hours under these conditions. The unit had an output of 100 gallons per hour for producing large droplets and 45 gallons per hour for dispersing insecticidal aerosol. Figure 4 shows the plane in operation dispersing DDT solutions. Table 3 shows the performance of the unit when dispersing a heavy solvent oil. Drop size data were not taken on these tests.

Swath widths from the Taylorcraft aerosol generator vary with the crosswind velocity, the height of release, and, to some extent with the average droplet size. When spraying at an altitude of 20 feet with a cross wind velocity of 7 to 10 m.p.h., the swath width is 60 yards with 85 per cent of the material deposited in a swath 30 yards wide. For other altitudes and wind velocities the swath width will change proportionally. These figures hold for the sprays produced at discharge rates over 75 gallons per hour. For aerosols dispersed at discharge rates under 60 gallons per hour the swaths are somewhat wider. Table 4 shows the swath widths required for different dosages and concentrations of solutions. In general, these are less than the actual swath widths so that overlapping will be required.

On light airplanes the downwash is small and aerosol applications produce low dosages dependent entirely on the prevailing meteorological conditions. Success ful use of this type of equipment for the control of mosquitoes over large areas of swamp land has already been reported (Krusé & Metcalf 1946).

Table 3.—Performance of *Taylorcraft* exhaust aerosol generator dispersing DDT solution.

R.P.M.	I.A.S., M.P.H.	Liquid Jet Dia., IN.	Oil Flow, GAL./HR.	Vacuum at Throat, IN. Hg		Exhaust Pressure, IN. Hg		Remarks
				Dry	Spraying	Dry	Spraying	
2350	110	—	—	—	—	—	—	Full throttle without generator
1500	60	0.25	60	2.5	1.6	0.8	1.0	¼" dia. venturi
1850	85	0.25	64	5.3	3.4	0.9	1.4	¼" dia. venturi
2100	95	0.25	83	12.3	6.2	2.4	3.4	¼" dia. venturi
1650	70	0.31	60	4.3	2.5	0.8	1.0	¼" dia. venturi
1850	85	0.31	87	6.2	3.0	0.8	2.0	¼" dia. venturi
2100	95	0.31	91	10.2	4.0	2.2	4.4	¼" dia. venturi

Similar installations were made on large military planes during the war. These gave excellent results in the control of mosquitoes when used for dispersing DDT solutions over heavily forested jungles where the downdraft forced the small aerosol droplets to penetrate the thickest vegetation.

Table 4.—Swath width-area dosages from *Taylorcraft* aerosol generator.[1] I.A.S., 90 m.p.h.; 2100 r.p.m.; Discharge Rate, 90 gal./hr. except for 20% solution where 60 gal./hr. is recommended.

DDT Dosage, lbs./acre	Swath Width, Feet		
	5% Solution	10% Solution	20% Solution
0.1	41	82	110
0.2	21	41	55
0.5	8	16	22
1.0	4	8	11

[1] The actual swath widths may be much greater than the figures shown so that overlapping will be necessary.

SUMMARY.—The need for simple, efficient equipment to disperse insecticides for mosquito control during the war led to the development of an exhaust aerosol or spray generator which could be used on readily available motor vehicles. The equipment consists of an insecticide reservoir, a control valve with indicating dial, a length of flexible hose, a simple clamp cutout and a sheetmetal venturi nozzle which is clamped on the exhaust stack of the engine. Insecticide solutions and emulsions made up in both high and low boiling solvents have been successfully applied with the equipment. The principle uses of the equipment up to the present time have been for fly and mosquito control with DDT solutions around public gathering places, drainage ditches, swamps, dairies, airplane hangars, auditoriums, and barracks. A detailed description is given of the equipment, its installation and the method of operating it when installed on the jeep. A similar device installed on the exhaust of light airplanes is also described. Suggestions are made on the usefulness of these devices for dispersing insecticides for the control of other insects, including agricultural pests.[1]

[1] *Acknowledgement.*—The assistance of Dr. Robert L. LeTourneau and Mr. Henry F. Hrubecky in assessing the distribution and drop sizes in the exhaust generated aerosols is gratefully acknowledged. The Orlando Laboratory of the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, carried out some of the tests on larviciding with the "jeep" generator. Helpful suggestions were also made by members of the staff of the Health and Safety Division, Tennessee Valley Authority and by personnel of the Bureau of Medicine and Surgery, U. S. Navy.

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NEW FIELD STATION IN TEXAS

I am wondering if it would be of interest to the readers of the JOURNAL to know that the Dallas, Menard and Uvalde, Texas stations will all be closed within a month and consolidated in one large new station at Kerrville, Texas. Some of our personnel has already been transferred to Kerrville and the balance will be transferred shortly. We hope to complete the consolidation by approximately January 15. In addition to the personnel at the three old Texas stations mentioned above we have added additional personnel from our Orlando, Florida station. Our staff at the new Kerrville station will include approximately 20 Entomologists and assistants and our work will be devoted almost entirely to external parasites of livestock.

The new station, all of which is now being built, will consist of one Administration Building, ten laboratory buildings, a shop and garage and other minor buildings, located on 1200 acres of ranch land of Highway 16, approximately five miles from the City of Kerrville. The City of Kerrville is located 65 miles northwest of San Antonio, Texas, in the "heart of the hills" in the midst of a diversified livestock area. E. W. LAAKE.

SCIENTIFIC NOTES

Airplane Spraying Apparatus for Mosquito Control

HAROLD R. YUST[1]

An apparatus for small airplanes which will give a fine spray deposit over a relatively wide swath is required in the application of DDT-oil solutions in and about military camps for the control of mosquitoes. For efficient control the apparatus should produce particles of a size effective against larvae and adults. A maximum number of droplets for a given volume is desirable for adequate coverage and yet the particles must be sufficiently large to settle rapidly even in a light breeze.

An effective device was developed by the writer while on duty with the United States Navy which gives a deposit of 100 or more droplets per square inch with an application rate of two quarts per acre and produces an excellent kill of larval and adult mosquitoes. The main feature of the apparatus is a spray rod and a one-piece dispersing device having the functions of a breaker strip, wind scoop and "drag" bar. The installation also includes an insecticide tank, pump, shut-off valve, connecting hose, and electrical facilities and connections for operating the pump. The equipment was installed on several *OY-1* United States Navy airplanes.

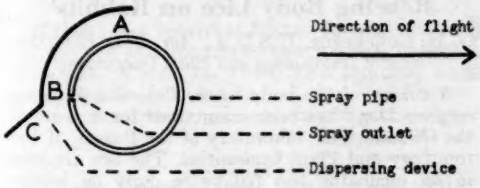

FIG. 1.—Cross section of spray pipe and the dispersing device having the functions of a wind scoop (A), breaker strip (B) and "drag" bar (C).

The DDT-oil solution is discharged under a pressure of approximately 50 pounds per square inch through a three-fourths inch (I.D.) pipe 10 feet long. The pipe is attached 8 inches below the fuselage directly behind the landing gear and extends on either side of the cockpit. The pipe is secured in the middle to the fuselage by two brackets and on the outer ends by struts attached to the wing supports. The insecticide is emitted from five holes on both ends of the pipe. The holes are 50 gauge (0.07 inches in diameter) and are 9 inches apart so that the solution is discharged from the outer 3 feet on both ends. The holes are directly opposite the leading surface of the pipe during flight. Both ends of the pipe contain threaded caps to facilitate removal of particles which may clog the outlet holes.

The dispersing device is made of 16 gauge sheet metal 2 inches wide (before moulding) and 42 inches long. It is moulded by bending a half inch of its entire length 45 degrees to produce the "drag" bar. The remaining sheet (1.5 inches) is moulded into an arc in the opposite direction (Fig. 1). The devices are bolted to the spray pipe 0.25 inch from the outlet holes on both ends of the pipe. The arc extends above the top of the pipe and serves as a wind scoop during flight. The outlet holes are opposite the lower portion of the arc which serves as a breaker strip. During operation the fluid impact is just above the original 45-degree bend. When the streams of insecticide strike the breaker strip some of the fluid is broken up into small particles. The function of the air scoop is to force the particles downward into the propeller wash. The remainder of the fluid is spread laterally over the half-inch "drag" bar by the air pressure on the flat surface and is dispersed in very small droplets as it leaves the trailing edge. The result is a continuous 42 inch spray on the outer ends of the pipe. Of course, additional dispersion occurs in the air slip. The device also greatly reduces wetting of the fuselage and tail assembly with insecticide.

The above described dispersing device was superior to one consisting only of the arc having the functions of a wind scoop and a breaker strip, or a device with only a flat breaker strip.

A deposit of at least 100 droplets per square inch was obtained over a swath of 100 feet at the rate of 2 quarts per acre. In practice, the most thorough coverage and the best control of mosquitoes was obtained by applying 5 per cent DDT in fuel oil at the rate of 1 quart per acre in one run and making a second trip over the area to double the rate of application.—4-4-46.

[1] Lieutenant, H(S), USNR, Inactive.

Control of the Sticktight Flea on Chickens

RICHARD, B. EADS, *Bureau of Laboratories, Texas State Department of Health, Austin, Texas*

The observations of Davis (1945) as to the ease with which the tropical rat flea, *Xenopsylla cheopis* (Rothschild), is controlled with DDT have been amply verified in subsequent typhus control programs by the United States Public Health Service, and at least two State Health Departments. In connection with DDT dusting of rat runs in a murine typhus investigation program being conducted in Lavaca County, Texas, there has been an excellent opportunity to make field tests on the control of the sticktight flea, *Echidnophaga gallinacea* (Westwood), on chickens.

Lavaca County is in the center of a chicken raising section, and it has been noted that a large percentage of the chicken farms are infested to varying degrees with *Echidnophaga gallinacea*. This flea frequently becomes of considerable economic importance, and in the past adequate control has been difficult to attain.

One objective of the Lavaca County typhus investigation program has been to study the efficiency of dusting rat runs with 10 per cent DDT dust in reducing the numbers of fleas and other ectoparasites. The runs are generally located in the barns where hay and feed is stored, and are not found in the hen houses. Although the hen houses are usually separate from the barns, as a favor to the farm owners it has been the practice to dust the hen houses as well as the barns in dusting operations whenever the number of fleas present warranted it.

Such excellent results have been obtained that it is thought of sufficient interest to be reported. The H. C. Randow chicken farm near Hallettsville,

Texas, was comparable in many respect to the 20 chicken houses that have been dusted at this writing, and the results obtained there are typical of those noted on the other farms.

The 175 chickens on the Randow farm were heavily infested with *Echidnophaga gallinacea*, and the one hen house which was used for both roosting and laying was very heavily infested with this flea. It was impossible to collect the eggs without becoming covered with fleas. Several hens were caught, and examined. The removal of 200 fleas from a typically infested hen did not materially affect the total number parasitizing her. This severe infestation was resulting in a very unthrifty condition, with a resulting increase in consumption of feed, and decrease in egg production.

The hen house was given a thorough application of 10 per cent DDT, the nests and roosts being liberally coated by means of a pint jar hand shaker, and the dirt floor of the roost and the walls dusted with a *No. 766 Hudson* hand duster. Approximately 2 pints of 10 per cent DDT dust were applied to the hen house which was 40 by 25 feet.

The day following the dusting, no sticktight fleas were in evidence in the hen house and the infestation on the hens seemed to be reduced. Within a week the hens were free of fleas, and no reinfestation has appeared at this writing, a month after the original dusting. There was no corresponding flea population drop on surrounding farms which were undusted.

SUMMARY.—From the experiences in field control of the sticktight flea, *Echidnophaga gallinacea*, on chickens, it is apparent that a thorough coating of the nests, roosts, and floors of the chicken houses with 10 per cent DDT dust will control the fleas, both free in the house and on the chickens themselves. It does not appear necessary to dust the chickens directly.—8-21-46.

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Injury to Fruit of Plums Caused by *Dicerca horni*

NORMAN W. FRAZIER, *California Agricultural Experiment Station, Berkeley*

The flat-headed borer, *Dicera horni* Crotch has been reported (Keen 1938) to be one of the species of dicerca beetles most frequently found breeding in the wood of forest trees in the western states. The larvae mine wood of dead spots on living trees as well as the wood of dead and dying trees (Doane *et al.*, 1936). The species occurs in a great variety of broad leaved forest trees and shrubs as well as in fruit trees, including cherry, peach, prune and plum (Essig 1926).

Although *Dicerca horni* is well-known to be destructive in its larval stages, a type of injury caused by the adult beetles was observed during late April and early May, 1946, which apparently has not heretofore been recorded.

Thinning crews working in plum orchards in a number of localities in Tulare County, California, observed and called attention to the fact that adult beetles were girdling the stems of immature plums, which caused the fruit to drop from the tree. Numerous such girdled and fallen fruits could be found on the ground. However, since most of the injury was sustained during the period when hand thinning was being carried on, little or no real loss resulted. The adult beetles were common but not abundant. Growers who were questioned stated that they had no previous knowledge of the insect or type of injury, which would indicate that for unknown reasons, the population of *Dicerca horni* this year was unusually high in the Tulare County plum orchards, sufficiently so to attract attention and cause some concern among growers for the first time.

This species has not assumed sufficient economic importance on other hosts to warrant the development of specific control measures. It is probable that orchard sanitation and other general preventive measures as recommended by Essig, 1926, for control of other flat-headed borers would be useful against *Dicerca horni* should the need arise.—8-20-46

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Rearing Body Lice on Rabbits[1]

G. H. CULPEPPER, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

A colony of the body louse, *Pediculus humanus corporis* Deg., has been maintained for 4 years at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine. The lice are kept in an incubator and fed twice daily on human hosts.

According to the literature, body lice have survived for 2 generations when fed on rabbits, but such colonies did not thrive. Recently, attempts have been made to rear lice from the Orlando colony by feeding them on rabbits.

Lice have been maintained successfully through six generations when fed twice daily on the shaved belly of a rabbit. Preliminary observations made on the third, fourth, and fifth generations indicate that the rabbit-fed lice live as long, reproduce as well, develop as rapidly, and are about as resistant to insecticides as are those fed on man. It may be that the Orlando colony, through 4 years of inbreeding, is adapted to laboratory rearing. Observations will be made using new stocks of lice collected from vagrants.

Detailed studies are being made with lice fed on several rabbits, since preliminary observations indicate that there is considerable variation among rabbits as suitable hosts.

Since lice from the Orlando stock, when fed on suitable rabbit hosts, can be maintained as a thriving colony, it is hoped that a technique may be developed whereby any entomological laboratory can maintain a colony of body lice using rabbits as hosts.—6-28-46.

[1] This work was conducted under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development and from the Office of the Surgeon General, U. S. Army, to the Bureau of Entomology and Plant Quarantine.

DDT to Control the Green Peach Aphis[1]

J. H. NEWTON and GEO. M. LIST,
Colorado Experiment Station,
Fort Collins

In the spring of 1945 the writes noted that the Winesap apple trees that had received 9 applications of DDT during the 1944 season for codling moth control showed little injury from rosy apple aphid, *Anuraphis roseus* (Baker), in comparison with trees that had been sprayed with arsenate of lead. The calyx and first two cover applications for codling moth control carried 0.4 pound of actual DDT to 100 gallons of water and the other applications carried 0.6 pound to 100 gallons of water. The last application was made August 12 and 13. The DDT used was a dry wettable powder of 40 per cent DDT content. By count the trees sprayed with arsenate of lead were found to have 42 per cent of the fruit spurs infested, while only 3 per cent were infested on DDT-sprayed trees. Steiner (1944) called attention to a similar condition in his codling moth experimental plots at Vincennes, Indiana. As a follow-up to this lead, parts of 3 peach orchards were sprayed September 26, 1945, with DDT (0.8 pound to 100 gallons of water) to determine whether similar results might be obtained with the green peach aphid, *Myzus persicae* (Sulzer). The result of counts made in the orchards March 28, 1946, are given in table 1.

Table 1.—A record of *Myzus persicae* (Sulzer) on sprayed and unsprayed peach trees, Palisade, Colorado, March 28, 1946. Two hundred buds examined in each sample.

Orchard Number	Infested Buds	Aphids Found		
		Stem Mothers	Young	Total
1. Old trees sprayed	3	6	9	15
1. Old trees unsprayed	121	131	210	341
1. Young trees sprayed	7	8	2	10
1. Young trees unsprayed	116	223	83	306
2. Sprayed	6	6	0	6
2. Unsprayed	19	21	1	22
3. Sprayed	1	1	0	1
3. Unsprayed	2	2	0	2
Total on treated buds	17	21	11	32
Total on untreated buds	258	377	294	671
Per cent reduction	93.41	94.42	96.26	95.23

The records were taken by selecting 10 twigs at random from each of 10 trees in a plot and recording the plant lice on two buds selected at random from each twig. Thus 200 buds from each plot were examined. The examinations were made in the orchard with a hand lens. It was thought that all eggs had hatched and, as the table shows, many stem-mothers were giving birth to young. A number of syrphus fly eggs were found but no predatory activity or parasitism was noted. In orchard 1, trees 4 years old and trees approximately 15 years old were sprayed and an adequate check for each retained. Orchards 2 and 3 consisted of full-bearing trees.

It will be noted that on the 800 buds from the untreated trees there was a total of 377 stem mothers, while the same number of buds from the treated trees carried only 21. This is a reduction of 94.4 per cent due to treatment. Because of the difficulty in making an accurate count of hatched and shriveled eggs in the orchard, a representative sample of twigs was collected from the old trees in orchard 1 on April 3 and counts were made in the laboratory by the use of a binocular on April 6. There were no aphids on 238 buds from the treated trees, while on 231 buds from untreated trees there were 48 stem mothers, 18 first-generation young, and 46 hatched and shrivelled eggs. Four syrphus fly larvae on the untreated twigs had undoubtedly destroyed several aphids. The count of eggs was influenced somewhat by the development of the buds and a loss of some bud scales.

It is clear that the treatments prevented much egg laying. This may have been due either to a destruction of the fall migrants or that of the sexual forms developing from them.

If fall treatment for the green peach aphis can be made successful it will have many advantages over spring treatment for Colorado peach growers. Fall weather and labor conditions are more favorable, water for spraying is available in irrigation ditches, and much fall feeding of the aphids is prevented. The latter is of major importance in view of recent findings of Daniels (1945) that the green peach aphid is a vector of peach mosaic virus.—7-18-46.

[1] Paper No. 218, Scientific Journal Series, Colorado Agricultural Experiment Station.

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The Nature of the Venom of *Formica exsectoides*

FRED ACREE, JR.,[1] ELIZABETH E. HAVILAND,[2] and H. L. HALLER[1]

The physiological action produced on the fingers by the venom of the ant *Formica exsectoides* Forel has recently been described by Haviland (1945). Contact of the venom with an abrasion produced a burning sensation similar to that caused by many acids. As a result of handling a large number of the ants during one day, and in spite of the hands having been rinsed in water at frequent intervals, the skin of the fingers became discolored and sloughed off after 6 days. The fingers ached severely for several hours and about 18 days were required for them to heal. Price (1945) stated that this ant ejected an acid secretion.

Stumper (1922, 1923) investigated the venom of some ants and reported that several species of the subfamily Camponotinae produced only formic acid, while several species of the subfamilies Myrmicinae and Dolichoderinae produced no formic acid; instead, the venom appeared to consist of proteins.

Since no previous chemical study appears to have been made on the venom of *Formica exsectoides*, it was of interest to determine its nature, especially in view of its physiological action and because of the difference in the constitution of the venoms reported on by Stumper.

[1] U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine.
[2] University of Maryland, College Park, Md.

The venom ejected by the excited workers has an acrid, penetrating odor similar to that of formic and acetic acids. Therefore, 389 living ants collected in February were anesthetized with ether vapor and ground in a mortar with a few milliliters of water. The total material was then steam-distilled completely, and the volatile acid fraction was reduced to a small volume after having been neutralized with 58.29 ml. of N/10 sodium hydroxide. The residue was steam distilled according to the method of Hillig & Knudsen (1942) and the fractions were redistilled. From a comparison of the distillation curves thus obtained with curves determined for pure formic and acetic acids, it was evident that formic acid was the only volatile acid component of the venom of *Formica exsectoides*, and that it occurred to the extent of 0.68 mg. per ant.

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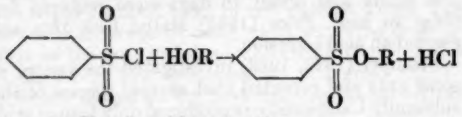
Toxicity of Aromatic Esters of Benzenesulfonic Acid to Codling Moth Larvae

E. H. SIEGLER and S. I. GERTLER, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

In a study of organic compounds for their possible value against codling moth larvae, *Carpocapsa pomonella* (L.), a number of aromatic esters of benzenesulfonic acid were tested.

All the esters were prepared by the reaction of benzenesulfonylchloride with various phenols by the Schotten-Baumann method. The reaction is shown by the following general equation, in which R represents the phenyl group, various substituted phenyl groups, or naphthyl groups:



Benzenesulfonyl chloride — Phenol — Ester

The toxicity tests were made with the apple-plug method, using approximately 100 plugs for each organic compound except (phenyl and *o*-tolyl esters of benzenesulfonic acid) with which 200 and 300 plugs were employed and about 500 and 400 plugs, respectively, for the lead arsenate and check tests. A single ready-to-hatch codling moth egg was confined with each apple plug.

All compounds were used at the rate of 4 pounds to 100 gallons of carrier which consisted of ethanol (95 per cent) 20 per cent and water 80 per cent.

Table 1.—Results of tests of some aromatic esters of benzenesulfonic acid against codling moth larvae.

NAME OF COMPOUND	FORMULA	PER CENT OF PLUGS	
		Wormy	Stung
Benzenesulfonic acid, *p*-chlorophenyl ester	$C_6H_5SO_3C_6H_4Cl$	19	1
Benzenesulfonic acid, phenyl ester	$C_6H_5SO_3C_6H_5$	22	2
Benzenesulfonic acid, *o*-tolyl ester	$C_6H_5SO_3C_6H_4CH_3$	45	3
Benzenesulfonic acid, *o*-chlorophenyl ester	$C_6H_5SO_3C_6H_4Cl$	54	0
Benzenesulfonic acid, *p*-tolyl ester	$C_6H_5SO_3C_6H_4CH_3$	81	0
Benzenesulfonic acid, *o*-nitrophenyl ester	$C_6H_5SO_3C_6H_4NO_2$	81	1
Benzenesulfonic acid, *p*-bromophenyl ester	$C_6H_5SO_3C_6H_4Br$	81	8
Benzenesulfonic acid, 2,4-dinitrophenyl ester	$C_6H_5SO_3C_6H_3(NO_2)_2$	86	4
Benzenesulfonic acid, *m*-tolyl ester	$C_6H_5SO_3C_6H_4CH_3$	87	0
Benzenesulfonic acid, 1-naphthyl ester	$C_6H_5SO_3C_{10}H_7$	89	5
Benzenesulfonic acid, *m*-nitrophenyl ester	$C_6H_5SO_3C_6H_4NO_2$	90	0
Benzenesulfonic acid, *p*-tert-butylphenyl ester	$C_6H_5SO_3C_6H_4C(CH_3)_3$	91	4
Benzenesulfonic acid, *p*-nitrophenyl ester	$C_6H_5SO_3C_6H_4NO_2$	92	0
Benzenesulfonic acid, 2-naphthyl ester	$C_6H_5SO_3C_{10}H_7$	92	2
Benzenesulfonic acid, 2,4,6-trichlorophenyl ester	$C_6H_5SO_3C_6H_2Cl_3$	93	0
Benzenesulfonic acid, xenyl ester	$C_6H_5SO_3C_6H_4C_6H_5$	93	2
Benzenesulfonic acid, 4-*tert*-butyl-2-chlorophenyl ester	$C_6H_5SO_3C_6H_3ClC(CH_3)_3$	94	0
Lead arsenate	$PbHAsO_4$	64	12
Check (untreated)	—	92	1

In comparison with lead arsenate, the *p*-chlorophenyl and phenyl esters of benzenesulfonic acid were considerably more toxic, the *o*-tolyl and *o*-chlorophenyl esters were somewhat more toxic, and the other esters were less toxic.

It is of interest to point out the effect on toxicity of substituting chlorine in the phenyl group of the phenyl ester of benzenesulfonic acid. The substitution of chlorine in the para position caused no change in toxicity, but the substitution in the ortho position decreased the toxicity. The substitution of additional atoms of chlorine, as in the 2,4,6-trichlorophenyl ester of benzenesulfonic acid, still further reduced toxicity.

DDT to Control Puerto Rican Mole Crickets

W. G. BRUCE, *U.S.D.A., Agri. Res. Adm., Bureau of Entomology and Plant Quarantine*

The writer and several neighbors in a housing project in Savannah, Georgia, suffered a considerable loss of flower and vegetable plants in 1945 due to the Puerto Rican mole cricket, *Scapteriscus vicinus* Scudd. Most of the damage was to seedlings and young transplants, but some plant injury was in evidence throughout the spring and summer months. No control measures were used because the recommended poison baits might harm the tender plants.

The mole crickets appeared again in the spring of 1946 and in a very short time killed about half the seedlings and transplants in a flower garden of about 300 square feet. Extensive destruction was also observed in flower and vegetable gardens nearby. The activities of the crickets were confined chiefly to the nighttime, when it was difficult to observe and destroy them. By the end of April the damage was so severe as to necessitate some kind of control or abandonment of the garden.

A DDT suspension containing 1.17 per cent of DDT (made by mixing 1 pound of 50 per cent wettable powder with 5 gallons of water) was applied, with a sprinkling can, to the soil of the flower garden at the rate of 1 gallon per 100 square feet. Damage from mole crickets was immediately stopped. Apparently the DDT killed all the crickets in the cultivated soil. Each night, however, a few crickets would migrate from the adjacent lawn to the garden, burrow for a few inches, and then disappear. One week after the treatment the same suspension was applied to a 4-foot strip of lawn bordering the flower garden. This completely eliminated the mole crickets from the flower garden for the rest of the season. A flower garden about 20 feet from the treated garden continued to have a large number of mole crickets as indicated by the numerous burrows observed each day and by the loss of plants.

A vegetable garden about 20 by 25 feet was heavily infested with the Puerto Rican mole cricket, and the young tomato transplants, string beans, peppers, cucumbers, and squash were severely damaged. A 1.17-per cent DDT suspension was applied, with a sprinkling can, between the rows of plants, care being taken to avoid getting it on the squash and cucumbers. The suspension was also applied to a strip of lawn about 4 feet wide adjacent to the garden. The dosage was approximately 1 gallon per 100 square feet. A little mole cricket activity was noted for about 2 days after treatment, but none thereafter for the rest of the season.

There was no ill effect noted on any of the plants grown in the treated soil.—10-9-46.

Control of the Red Harvester Ant with *Velsicol 1068*

CHARLES H. BRETT and W. C. RHOADES,[1]
Oklahoma Agricultural Experiment Station, Stillwater

The red harvester ant, *Pogonomyrmex barbatus* var. *molefacians* (Buck), is one of the major pests of fields, pastures, and yards in Oklahoma. Over a period of years tests have been made with many different insecticides in the study of its control. The old standards, calcium cyanide and carbon disulfide, while effective, offer such dangers to the user that they have been recommended with hesitancy. Some success has been had in controlling these ants with a solution of paradichlorobenzene in carbon tetrachloride but such treatment has often required several re-applications.

This paper reports results which were had using the new synthetics, *Velsicol 1068* and hexachlorocyclohexane.

PROCEDURE.—The campus of the Oklahoma A. and M. College and the various experimental pastures, dotted with hundreds of ant mounds, offered an ideal situation for the experiment. Large, well established colonies were selected. These were mapped and grouped in blocks of four. Each colony was examined at the end of 1, 2, 4, 8, and 24 hours after treatment, then once each day during the first week and once each week for 8 weeks.

Colonies were disturbed as little as possible. Solutions were poured into the mound openings slowly in order that they might drain into the tunnels. No coverings were placed over the mounds. Most of the colonies were treated during early morning hours.

Table 1 shows the concentration and volume of technical 1068 solutions used in the test. Hexachlorocyclohexane was applied as a 1 and 2 per cent gamma isomer, water suspension. Treatments were made with 100 and 200 cc. of these preparations. A few mounds were ringed with the dust which contained 5 per cent gamma isomer.

RESULTS.—Application of technical *Velsicol 1068* solution stimulated considerable activity in the ant colonies. Within an hour after treatment many of the insects twitched spasmodically even where the lowest concentrations were used. Numbers of ants were dead before the end of the second hour.

Table 1.—The effectiveness of different concentrations of technical *Velsicol 1068* in controlling the red harvester ant.

Concentration Technical 1068 Vol./Vol.	Number of Colonies Destroyed (Four Colonies Treated with Each Concentration)			
	100 cc. solution per colony		200 cc. solution per colony	
	Diluent		Diluent	
	Carbon Tetrachloride	95% Alcohol	Carbon Tetrachloride	95% Alcohol
0.0	0	0	0	0
0.5	0	0	0	0
0.75	0	0	0	0
1.0	2	1	3	2
1.5	2	2	4	3
2.0	3	3	3	4
2.5	3	4	4	4
3.0	4	4	4	4
5.0	4	4	4	4

Ants were not repelled from their tunnels. Incoming individuals entered them readily. An unusual aspect in comparing technical *Velsicol 1068* with other materials was the large numbers of insects which died outside of the nest. The area around a mound within about an 8-foot radius became littered with the bodies of hundreds of ants.

At the higher concentrations (2.5 to 5 per cent technical *Velsicol 1068*) nests were destroyed within 24 hours. There were no re-establishments of colonies in new places.

Hexachlorocyclohexane suspension killed large numbers of ants at the time of application, but a repellent effect was evident. Parts of the colony set up new entrances, thus establishing 2 or 3 new nests near the original one. Barriers of the dust containing 5 per cent gamma isomer, which were placed around mounds, killed many of the ants which crossed them within the first 72 hours. During this time the barriers were repellent, causing numerous insects to turn away. After 72 hours, ants crossed the dust readily and showed no effects. None of the colonies treated with this dust were completely destroyed.

CONCLUSIONS.—Solutions of technical *Velsicol*

[1] Respectively, Assistant entomologist and research assistant.

1068 controlled the red harvester ant more effectively than any material which has yet been tested. Results of this experiment show that 100 cc. or more, depending upon the size of the colony, of a 2.5 to 3 per cent solution will destroy a nest within 24 hours. These results have been further verified at the Oklahoma Agricultural Experiment Station by a general control program in which over 300 colonies in pastures and yards were destroyed by pouring one cup (about 200 cc.) of 3 per cent *Velsicol 1068* solution into the opening of each colony. Carbon tetrachloride and 95 per cent alcohol were used as satisfactory solvents for the technical concentrate. Other diluents such as petroleum oils or water suspensions have since been found to serve as well.

The toxic effect of *Velsicol 1068* on warm-blooded animals was not known. It was used cautiously during this experiment with no effect on the operators other than a slight irritation of the nose and eyes caused by fumes from the concentrate.

Hexachlorocyclohexane killed large numbers of ants but did not destroy any colonies, apparently because of its repellent effect and its loss of toxicity after 72 hours.

Control of Lygus Bugs with DDT as Related to Guayule Seed Production

VAN E. ROMNEY, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Guayule, *Parthenium argentatum* Gray, tends to flower more or less continuously during the growing season if soil moisture is adequately maintained. Under such conditions new flowers continue to appear, but the plants bloom more freely after irrigations, and irrigated areas in California have been found to provide environments conducive to the developments of successive generations of *Lygus* bugs.

Hills & McKinney (1945) found that 5- and 10-per cent DDT dusts were very effective against *Lygus* bugs on seed beets under field conditions, and that the material did not injure the plants or the seed. Lieberman (1945) reported that 10-per cent DDT dust was effective against *Lygus* bugs on alfalfa seed, showing a residual effect for over a week and resulting in a higher quality of seed and in no plant injury. Romney *et al.* (1945) showed that both 5- and 2.5-per cent DDT dusts applied to field plots at an average rate of 33 to 34 pounds per acre reduced *Lygus* bugs and increased the viability of guayule seed.

During the 1945 season an experiment was conducted near Salinas, Calif., to determine the effect of DDT dust on the quality and quantity of guayule seed by treating field plots of variety "593" often enough to keep populations of *Lygus hesperus* Knight comparatively low. The results of that field experiment are presented in this paper.

METHODS.—The experiment consisted of 12 plots 44.5 feet square, 6 of which were treated with DDT dust and 6 were untreated checks. A 2.5-per cent DDT dust was made by diluting a commercial 10-per cent dust with pyrophyllite. The dust was applied with a rotary hand duster at rates of 30 to 35 pounds per acre.

Lygus counts were made by means of a sampling cage, described by Hills (1933), with an added feature consisting of a square semisplit canvas to be drawn around the base of the plant after the sampler was set over it. After removal of the adults that had accumulated around the celluloid lid of the cage, the plants were shaken briskly. This caused the nymphs to fall onto the canvas base, and thus facilitated the counting. Five plants taken at random were sampled from each plot.

Five plants in the central part of each plot were tagged, and from them guayule seed was collected by hand as often as was necessary to prevent excessive loss from shattering. It was obvious that a large part of the adult *Lygus* population was driven from the plants each time seed was collected, but the nymphs were not materially disturbed. The seed was cleaned by mechanical means. The percentage of filled seed was determined by threshing 500 seeds from each plot sample. The mechanical thresher removed the seed husks, leaving the empty and the filled pericarps. These pericarps were poured into acetone, wherein the filled seeds settled to the bottom, while the empty ones floated. Benedict & Robinson (1946) showed that the filled-seed count obtained by the above-mentioned method averaged 95 to 98 per cent viable.

RESULTS.—The 2.5-per cent DDT dust killed most of the *Lygus* adults and nymphs present at the time the applications were made, but there was little,

Table 1.—Weight and percentage of filled guayule seed from 6 plots treated for control of *Lygus* bugs and from 6 untreated plots.

Date of Seed Collection, 1945	Untreated Plots			Treated Plots		
	Total weight of cleaned seed from 30 plants	Average weight of 500 seeds	Filled seed	Total weight of cleaned seed from 30 plants	Average weight of 500 seeds	Filled seed
	Grams	*Grams*	*Per Cent*	*Grams*	*Grams*	*Per Cent*
July 7	54.0	0.93	29.1	57.5	1.00	38.3
30	53.8	.83	15.9	59.2	.92	29.1
August 24	78.9	.88	24.2	91.7	.98	40.3
September 1	50.5	.88	13.2	56.5	1.04	36.3
8	26.7	.77	7.8	51.9	1.02	46.6
17	33.1	.62	4.1	59.3	.88	42.1
29	6.7	.56	6.0	38.2	.85	51.7
Total	303.7	—	—	414.3	—	—

if any, residual effect shown against the nymphs that hatched after treatment. The problem of adult reinfestation into the small plots also had to be considered.

Lygus counts made 4 days after the first application (May 28) showed no adults and 41 nymphs on 30 plants sampled at random in the treated plots, as compared with 11 adults and 308 nymphs in the checks. Eleven days after the first treatment there were 6 adults and 151 nymphs in the treated plots, as compared with 16 adults and 514 nymphs in the untreated checks.

The second application was made on June 11, and 5 days later there were 29 adults and 13 nymphs in the samples from the treated plots, as compared with 155 adults and 479 nymphs in the checks. Thirty-one days after the second treatment samples from the treated plots contained 118 adults and 81 numphs, as compared with 150 adults and 173 nymphs in the checks.

The third application was made on July 12 to reduce the number of adults, most of which had shifted into the treated plots from adjacent guayule. Three days after the third treatment samples from the treated plots contained 18 adults and 1 nymph, and 11 days later samples from the same plots yielded 18 adults and 352 small nymphs.

The fourth application was made on July 26 and 4 days later there were no adults and 13 small nymphs in samples from the treated plots, as compared with 30 adults and 831 nymphs in the checks. Twenty-nine days after the fourth application there were 7 adults and 209 nymphs in the treated plots, as compared with 42 adults and 510 nymphs in the checks.

By this time it was evident that the plants had stopped producing new flowers; so a fifth, and final, application was made on August 25 to reduce populations in the treated plots. Three days later there were 2 adults and 4 nymphs in samples taken from the treated plots, as compared with 69 adults and 165 nymphs in the checks. At this time in the treated plots there were obviously more flowers with a tendency to mature slowly than in the untreated plots.

The quality of guayule seed was sustained at a high level by the DDT dust treatments. (See table 1.) Seed from guayule variety "593" germinates only about 50 per cent under favorable conditions, owing to the reproductive peculiarities of the plant; therefore the filled-seed counts from the treated plots were high. The amount and quality of seed in the untreated plots decreased rapidly after the September 1 collection, while heavy production of high-quality seed was maintained in the treated plots. In the treated plots the weight of 500 seeds decreased on the last two collection dates, while the amount of filled seed remained high. This was due to the fact that smaller seeds were produced by the plants at that time. There was also a 26.8-per cent increase in the weight of cleaned seed taken from the treated plots over that from the check plots.

SUMMARY.—Five applications of 2.5-per cent DDT dust were made between May 28 and September 28, 1945, to control two generations of *Lygus hesperus* Knight in guayule-seed plots near Salinas, Calif. The dust was applied with a rotary hand duster at the rate of 30 to 35 pounds per acre.

The 2.5-per cent DDT dust killed most *Lygus* bugs present at the time applications were made, but it showed no residual effect on nymphs that hatched after application; therefore a second application was required about 10 days later, to control a given population of the insect. These treatments effected an average filled-seed count of 40.6 per cent in the treated plots, as compared with 14.3 per cent in the untreated plots. The treated plots also produced 26.8 per cent more cleaned seed by weight than did the untreated checks.

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Isopropyl Alcohol and Phenol Used in Entomological Microtechnique

H. H. KEIFER, *California State Department of Agriculture, Sacramento*

In the course of devising improvements for critical preparation of certain insects for identification purposes, the following techniques proved to be practical.

Materials for clearing, staining and mounting of scale insects and mealybugs are: 1, water in phenol solution; 2, lactic acid 85%; 3, NaOH pellets or flakes; 4, anhydrous isopropyl alcohol; 5, basic fuchsin powder; 6, xylene; 7, glacial acetic acid; 8, balsam, clarite, or some non-crystalline transparent mounting medium soluble in xylene.

The steps are: first, boil the insect in a mix of lactic acid and phenol sol until the whole body shows penetration and partial interior dissolving. (A cut in the side of the insect helps.)

Second: transfer to, and boil the specimens in NaOH solution, pressing out the body contents gently.

Third: transfer specimens to the phenol solution and boil until interior soft tissue has disappeared.

Fourth: transfer to moderately strong basic fuchsin solution in isopropyl alcohol. The specimens can be left for a while in this solution, although sufficient staining develops very quickly.

Fifth: transfer specimens to xylene solution; there should be but a small quantity of this xylene in the bottom of a watch glass. Place the watch glass under the binoculars for observation, and carefully drop isopropyl alcohol onto the specimens in xylene, for destaining to proper color intensity. If, after the addition of much isopropyl alcohol, the specimens still remain too dark (chitin should be quite light and sclerotin bright magenta), carefully drop in glacial acetic acid.

Sixth: as the specimens become destained sufficiently transfer to straight xylene.

Seventh: transfer the specimens from xylene to the non-crystalline mounting medium on a slide.

This procedure cleans out the inner tissue better in a number of cases than straight NaOH, and the xylene treatment of basic fuchsin gives a bright magenta color. When taken through glacial acetic and clove oil, fuchsin tends to be a distinctly duller purple.

The addition of a small percentage of phenol to aphid preparatory media is a distinct advantage. A formula is:

Lactic acid 85%	20 parts
Glacial acetic acid	4 parts
Phenol (melted)	4 parts
H_2O	2 parts

Iodine crystals dissolved in this medium can be helpful, staining colorless specimens sufficiently to keep them from being lost.

After heating in the above medium at 60°-80° C for several hours, gently squeeze the aphids to press out the dissolved interior. Then place them directly into phenol-xylene solution and so on into balsam. Or put directly into isopropyl alcohol fuchsin staining solution, etc.

There are very many varieties of so-called gum-chloral or chloral hydrate media. The one outlined below is temporary, as it will destroy the specimen after several days, but can serve as a "speed-mount" during identification of large numbers of specimens. Valuable insects are recoverable from this speed mount for permanent embedding in balsam, if not left too long.

Gum Arabic	1 gram
Dextrose	1 gram
Chloral hydrate	10 grams
KI	.15 gram
Iodine	Small amount
Glycerin	20 drops
HCl 10% from the commercial solution	18–20 drops

Add sufficient iodine to make the solution quite dark. Place specimens directly in this medium and warm gently under the coverslip.

Gum arabic (acacia gum) is the usual non-crystalline transparent basis for water soluble media. While gum arabic is not a perfect substance for microtechnique, no water soluble synthetic polymer is very similar. Such water soluble plastics as polyvinyl alcohol are rubbery, and absorb a large quantity of solvent, which results in considerable changes in volume when drying. This rubbery condition is due partly to molecule type, and also to molecule length. If the polymerization of special batches of these plastics would be stopped while the molecules are still quite short, the resulting substances would be much more satisfactory for the microtechnique described above.—6-18-46.

Unsatisfactory Control of Plum Curculio in Illinois with Dichloroethyl Ether

S. C. CHANDLER, *Illinois Natural History Survey*

During the season of 1946, an attempt was made to duplicate under Illinois conditions the results obtained in Georgia by Oliver I. Snapp with dichloro ethyl ether for control of the plum curculio. His publication, USDA Bureau of Entomology & Plant Quarantine E-558, and articles in the JOURNAL OF ECONOMIC ENTOMOLOGY, as well as personal correspondence were used as guides.

Tests were carried on in two orchards—the Sauer orchard in the latitude of Carbondale, and the Bates orchard 60 miles north near Centralia. In the Sauer orchard, dichloro ethyl ether was emulsified with fish oil soap according to directions in E-558. In the Bates orchard, it was emulsified by the G. S. Robbins Co. of St. Louis and a 97 per cent stock delivered to the orchard.

First application was made to the ground in the Sauer orchard on June 13, when most of the larvae had left the drop peaches; 800 gallons were applied to approximately 200 trees. It was begun June 11 in the Bates orchard. Several days were required for this as at least 75 acres were covered. The second application was started on June 21 in the Bates orchard, and on June 27 in the Sauer orchard. Dichloro ethyl ether at 1.5 per cent was used in the first application and 4.5 per cent in the second. The rate of application used by Snapp in Georgia (one gallon to six square yards of area under the spread of the branches) necessitated the use of approximat ely four gallons per tree, which is a larger amount than the greatest suggested by Snapp and due to the greater size of trees in Illinois.

In the Bates orchard, due to the heavy infestation in 1945 and the outlook for a repetition in 1946, drops were picked up and removed over most of the "home orchard" leaving a small check which received no soil treatment or drop removal. This removal of wormy dropped peaches is rarely practiced in Illinois because it has not been considered economical.

Data on control were obtained by two methods—jarring for adult curculios and making infestation counts at harvest.

JARRING.—Jarring was done with two sheets approximately 6 ft. by 9 ft. under each tree, making only one placing of the sheets even though the trees in many cases represented a larger area than the two sheets. In the Sauer orchard, regular jarring of 10 trees was made at approximately weekly intervals from the shuck split stage (April 3) and was continued nearly to harvest. The spray blocks were arranged so that half of the 10 trees jarred each week fell in the part receiving two ground applications of dichloro ethyl ether, and half in the untreated area. Up to the time of spraying, there was very little difference between numbers jarred in each half. After treatment, 10 more trees were jarred—an additional 5 in the treated and 5 in the untreated. On July 2, five days after the second treatment, jarring was started in the two areas as just described. Numbers of plum curculios caught in the two areas are as follows:

Sauer Orchard
Plum curculios jarred from 10 trees

DATE JARRED	TREATED AREA	UNTREATED AREA
July 2	24	48
July 8	51	60
July 12	36	46
July 19	9	5
July 24	16	24
Totals	136	183

Final infestation counts
Sauer orchard[1]

Plot No.	Treatment	Number of Wormy Peaches in 500	Per Cent Infested
1	2 soil treatments 3 late poison dusts	15	3.0
3	no soil treatment 3 late poison dusts	17	3.4
3	no soil treatment no late poison dusts	52	10.4
4	2 soil treatments no late poison dusts	50	10.0
5	1 early soil treatment 3 late poison dusts	32	6.4

In the Bates orchard, there was no background of jarring data; so exploratory jarring only was made once, July 13, 23 days after the second application. The orchard in which the drops were picked up was given only the first application. The other orchard received one application over all the area and two applications over parts of it. The following numbers of curculios were jarred in the several blocks:

Bates Orchard
Plum curculios jarred from 5 trees

Orchard	Treatment	July 13
Home	Drops picked up, one early spray	9
Home	No treatment	17
Hard road	Area 1	
	2 sprays	2
	1 spray	4
Hard road	Area 2	
	2 sprays	6
	1 spray	8

There were two treated blocks; one receiving the first application only and one the two sprays. Two lead arsenate sprays and six dusts had been applied up to June 27, the time of the second soil application. Three more poison dusts were applied after that time up to harvest, July 31, except to a small area at one edge and including both the area which had received the two ground sprays and the check which had received none. Five hundred peaches were examined in each of the five blocks. Records were kept by hundreds with fairly uniform numbers in each hundred. They are summarized as follows:

[1] Differences between plots significant at the 5 per cent level but not at the 1 per cent level. At 5 per cent level a difference of 5.66 is necessary for significance.

Bates Orchard

Orchard	Plot No.	Treatment	Number of Wormy Peaches in 500	Per Cent Wormy
Home	1	no soil treatment no drops picked up	29	5.8
Home	2	1 early soil treatment drops picked up	8	1.6
Hard road	3	2 soil treatments	9	1.8
Hard road	4	1 soil treatment	7	1.4

The entire Bates orchard received 4 poison sprays and 8 poison dusts up to July 1, and 2 poison dusts between then and harvest, August 7. Infestation counts were made in most of the same blocks which were jarred, and in the same locations.

DISCUSSION AND CONCLUSIONS.—These data must be considered as a whole to arrive at right conclusions. Due to the heavy spray and dust programs in both orchards, the level of infestation was brought down to a point where there could be some doubt as to the significance of infestation data in some cases. However, when the very little differences between treated and check in numbers of curculios jarred in the Sauer orchard are compared with the harvest data from Plots 1 and 2, there is considerable evidence that the two soil treatments of dichloro ethyl ether were of very little value.

In the Bates orchard, the only absolute check was in the home orchard, which received only the one soil application; and there is no way of knowing how much of the reduction indicated by the jarring records (home orchard) and by the final infestation records (Plots 1 and 2) was due to picking up drops and how much to the one early soil application. The fact that neither the jarring in the Bates (hard road) orchard nor the final infestation counts show any appreciable differences between one and two soil applications when taken in conjunction with data from the Sauer orchard indicates that in this orchard also, the poison applications to the fruit were responsible for most of the control of plum curculio.

Since the control indicated by these Illinois data is so decidedly inferior to that obtained by Snapp in Georgia, it is suggested that experimenters in other peach areas in this latitude and farther north test this control measure in their own sections. We have only two possible explanations. At the first application, there may have been a sufficient growth of grass and weeds so that enough of the material did not readily reach the ground. Correspondence with Snapp indicated that this was no factor in Georgia, but might be in Illinois. To make sure, I got the owners to disc the soil before the second application. The other possible explanation is tightness of soil. The Sauer orchard is located in the unglaciated area of the state, on a type of soil classed as fine sandy silt loam. The Bates orchard is located on soil typical of most of southern Illinois north of Carbondale classed as gray silt loam on tight clay. It is just possible that the material does not penetrate sufficiently well in either of these two types of soil.—10-1-46.

DDT Aerosols to Control Worms in Corn

L. P. DITMAN, *College Park, Maryland*

Preliminary tests were conducted, during the summer of 1945, to determine the value of DDT liquefied gas aerosols in protecting sweet corn ears from *Heliothis armigera* (Hübn.), *Pyrausta nubilalis* (Hübn.), and *Laphygma frugiperda* (S. & A.). A knapsack type of dispenser (Fig. 1) equipped with six oil burner nozzles, three directed to each side, with the middle nozzles at the height of the average ear, was used for applying the aerosol. A low pressure oxygen tank was used for storage of the liquefied gas aerosol solution. All treatments were made with a 5 per cent aerosol containing in addition 50 per cent methyl chloride, 10 per cent *Velsicol AR-60*, and 35 per cent acetone. The treatments were applied by walking between the rows at a rate of approximately 3 miles per hour.

FIG. 1.—Aerosol dispenser designed and used for treating corn. The insecticide is applied by carrying the dispenser between corn rows.

The first test was conducted on five plots of corn, which received the following treatments: Plot 1. Received three applications of aerosol, the first on August 14 when the ears were small and before silks began to appear; the second, on August 22 when silks were appearing; and the third on August 28 after all silks were out. Each treatment was applied by carrying the dispenser once through each inter-row space. Plot 2. Received applications of aerosol at the same time as Plot 1. The insecticide was applied by carrying the dispenser through every other inter-row space. Plot 3. Treated in the same manner as Plot 1 except that only 1 application of aerosol was made, on August 28, when plants were in full silk. Plot 4. Insecticide applied as in Plot 2, but only one application on August 28. Plot 5. Untreated check. The crop was harvested on September 11 and the results are given in table 1.

Table 1.—Ear infestation in first test of aerosols against lepidopterous larvae in sweet corn.

Plot	Per Cent Ears Clean	Per Cent Ears Injured by: Ear Worm	Corn Borer	Fall Armyworm	Total Ears
1	35.6	59.4	3.9	.9	101
2	9.9	79.7	9.0	1.3	222
3	13.6	58.5	15.6	12.2	147
4	12.8	64.2	8.5	14.3	70
5	12.6	61.5	4.4	21.4	182

The second test was conducted on three plots of late sweet corn which had heavier infestations of all three species than the earlier corn. Plot 1. Received two applications, the first on August 31 when silks were first appearing and on September 4 after all the silks were out. The dispenser was carried through every other inter-row spice. Plot 2. Received treatments at the same time as plot 1 except that applications were made by carrying the dispenser through every inter-row space. Plot 3. Untreated check.

Table 2.—Infestation of ears in the second test with DDT aerosol against lepidopterous larvae in sweet corn.

Plot	Per Cent Ears Clean	Per Cent Ears Infested by: Ear-worm	Corn Borer	Fall Armyworm	Total Ears
1	15.3	75.0	6.2	3.5	144
2	25.2	71.2	2.1	1.4	139
3	0	51.2	3.6	45.2	166

The crop was harvested September 21 and the results of total infestation of the ears is given in table 2. The fall armyworm infestation had become quite heavy on this later planting causing serious injury to the ears. Observations on the extent of this type of damage are therefore given for plots 2 and 3 in table 3.

Table 3.—Observations of the extent of shank or butt injury to corn ears by the fall armyworm on plots 2 and 3 of second test.

Plot	Per Cent with No Butt Injury	Per Cent with Butt Entrances	Total Number of Ears
2	98.3	1.7[1]	120
3	62.8	37.2	180

[1] One European corn borer larva and one armyworm larva.

The 5 per cent DDT aerosol caused no serious plant injury. It was not effective against the corn earworm and the European corn borer, but greatly reduced the fall armyworm population, particularly in the ears. This greater effectiveness may be due to the habit of the fall armyworm of moving about more freely on the corn plant. The fall armyworm is the limiting factor in the production of fall sweet corn in southern Maryland and the effectiveness of DDT against it is therefore of particular interest.—7-6-46.

DDT Dusts and Sprays, and Bran Baits Containing Different Poisons, for Armyworm Control

C. M. PACKARD, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[1]

An outbreak of the armyworm, *Cirphis unipuncta* (Haw.), in Princess Anne County, Va., late in April 1945 afforded an opportunity for a few experiments with DDT dusts and sprays, as well as with several bran baits containing an arsenical or fluorine compound as the poisonous ingredient.

The DDT preparations used were as follows: Dusts containing 2 and 10 per cent of DDT in pyrophyllite; 1 spray containing 2 pounds of DDT per 100 gallons of water, made from a commercially prepared water-dispersible powder; and 1 spray containing 5 per cent of DDT in kerosene. These insecticides were applied about 6 P.M. on April 27, by means of hand equipment, to heavily infested plots of tall, headed-out rye. Each dust or spray was applied once to a different plot about 37 feet square. One application of the DDT-kerosene spray was made to a 4- by 36-foot plot in the same field at 1 P.M. on April 29. Mortality was determined by carefully examining the litter at the bases of the plants and the adjacent soil surface in several places on a plot until 100 worms had been found. The rates of application and the results are given in table 1. The results indicate that either the armyworm is not highly susceptible to DDT in dusts or sprays or the action of DDT on this insect is very slow.

Table 1.—Armyworm mortality and DDT residues following application of DDT dusts and sprays to infested rye.

DDT Preparation	DDT per Acre	Date Applied	Mortality		DDT Residues	
			April 29	April 30	May 26	June 5
	Pounds		*Per Cent*	*Per Cent*	*P.p.m.*	*P.p.m.*
2 per cent dust	0.9	Apr. 27	32	23	4.6	3.3
10 per cent dust	4.5	27	53	39	12.2	3.3
Water spray	2.0	27	27	12	8.4	3.0
Kerosene spray	30.0	29	—	8	—	—
Check, untreated	—	—	1	4	—	—

DDT residues remaining on the rye at harvest time are also shown in table 1. These were determined[2] from small bundles of entire plants, exclusive of crowns and roots, taken from the treated and the untreated plots.

Five baits, each containing 25 pounds of wheat bran and a different poison, and moistened with water to make a crumbly mash, were broadcast by hand on single 1-acre plots between 5 and 6:30 P.M., on April 28. These plots were in the same field of heavily infested rye as the DDT-treated plots already described. The poisons used and the results obtained are given in table 2. The method of determining mortality in these plots was the same as that used in the plots treated with DDT.

Table 2.—Armyworm mortality following application of poison-bran baits to infested rye.

Poison	Quantity Per 100 Pounds of Bran	Mortality	
		April 29	April 30
	Pounds	*Per Cent*	*Per Cent*
Paris green	4	81	94
Calcium arsenate	4	26	81
Calcium arsenate	6	24	93
Sodium fluosilicate	4	80	91
Cryolite	6	18	38
Check, untreated	—	1	0

From the results of the bait experiments just described the following conclusions may be drawn: (1) Paris green is a very effective poison on armyworm bait; (2) calcium arsenate is an effective poison for the armyworm, but is considerably slower in action than paris green; (3) calcium arsenate at 6 pounds per 100 pounds of bran is preferable to 4; (4) sodium fluosilicate at 4 pounds per 100 pounds of bran is about as effective as paris green used at the same rate; and (5) cryolite used at the rate of 6 pounds per 100 pounds of bran is comparatively ineffective against the armyworm.

[1] Much assistance in these experiments was given by L. W. Brannon, entomologist, Bureau of Entomology and Plant Quarantine, H. G. Walker, entomologist, Virginia Truck Experiment Station, H. W. Oslin, county agent of Princess Anne County, Va., A. L. Curtis, assistant county agent of Princess Anne County, and Elwood Land, on whose farm the experiments were conducted. Their cooperation is gratefully acknowledged.

[2] In the Division of Insecticide Investigations, Bureau of Entomology and Plant Quarantine, by the chlorine method.

Metastability and the Efficiency of Azobenzene as a Fumigant

S. E. SHARP, *Iowa State College, Ames*

The observations of Blauvelt (1945) indicate a remarkable efficiency of azobenzene when used as a greenhouse fumigant for the red spider. His method of application was to paint the compound in the form of a paste on the greenhouse steam pipes, then turn on the steam to heat the pipes and so volatilize the substance. The present study was undertaken to determine the physical state of the volatilized azobenzene when coming in contact with a surface.

Glass slides, housefly wings, and alfalfa leaves were suspended at various levels in a bell jar supported on a wooden platform. A crucible was fitted into a hole in the bottom of the platform, and measured quantities of azobenzene volatilized into the chamber by moderate heating of the material in the crucible on an electric hot plate.

The chamber was allowed to remain undisturbed for 5 minutes after volatilization was complete, then

the slides were removed for microscopic examination. It was found that the azobenzene formed on the slides in an even pattern of very finely divided drops, appearing, in low concentrations, like condensed water vapor. A similar condensation pattern was found on the fly wings and on the alfalfa leaves. Comparable results were obtained when the azobenzene was volatilized in a 125 cu. ft. fumigation chamber.

The droplets did not crystallize, but remained in the liquid state for a period of several hours, even though the slides were maintained at 40 to 45 degrees below the freezing point (68°) of the azobenzene. The finer drops slowly evaporated without crystallization; the larger drops finally crystallized. Azobenzene thus exhibits to an unusual degree the property of metastability, which may be defined as that state of existence illustrated by a fluid capable of maintaining the liquid state below its freezing point. The metastability of azobenzene is indicated in the experiments of Friedlaender & Tammann (1897).

It is suggested that the efficiency of azobenzene when used as a fumigant is due to its metastability. The fine, mist-like liquid particles of the compound settling out on the insects and the foliage offer maximum opportunity for contact with the cuticle and for subsequent penetration.—9-10-46.

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Toxicity of Some Alpha Tolunitriles and Glycinonitriles to Codling Moth Larvae

E. H. SIEGLER and S. I. GERTLER, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

The results of laboratory tests of certain alpha tolunitriles and glycinonitriles against larvae of the codling moth, *Carpocapsa pomonella* (L.), are given in this paper.

The compounds were prepared under varied conditions by the condensation of an aldehyde and an amine with potassium cyanide. The general reaction for the preparation of the tolunitriles may be illustrated by the following formulas, in which R_1 represents the aryl portion of the aldehyde and R_2 the radical attached to or including the nitrogen of the amine. In preparing the glycinonitriles formaldehyde was used, and therefore R_1 would be replaced by hydrogen.

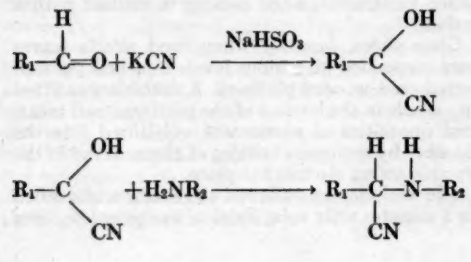

Table 1.—Toxicity of certain nitriles to codling moth larvae.

Compound	Formula	Per Cent of Apple Plugs	
		Wormy	Stung
N-*p*-Tolylglycinonitrile	$C_6H_4CH_3NHCH_2CN$	16	1
o-Hydroxy-α-1-piperidyl-α-tolunitrile	$CH_2(CH_2)_4NCHCNC_6H_4OH$	32	0
N-Phenylglycinonitrile	$C_6H_5NHCH_2CN$	67	2
α-*p*-Bromoanilino-α-tolunitrile	$BrC_6H_4NHCHCNC_6H_5$	73	0
α-Anilino-α-tolunitrile	$C_6H_5NHCHCNC_6H_5$	78	0
N-*o*-Anisylglycinonitrile	$C_6H_4OCH_3NHCH_2CN$	81	0
α-(1-α-Naphthylamino)-α-tolunitrile	$C_{10}H_7NHCHCNC_6H_5$	86	0
p-Methoxy-α-1-piperidyl-α-tolunitrile	$CH_2(CH_2)_4NCHCNC_6H_4OCH_3$	86[1]	1
α-1-Piperidyl-α-tolunitrile	$CH_2(CH_2)_4NCHCNC_6H_5$	88	0
α-*o*-Anisidino-α-tolunitrile	$C_6H_4OCH_3NHCHCNC_6H_5$	88	0
α-*p*-Toluino-α-tolunitrile	$C_6H_4CH_3NHCHCNC_6H_5$	89	1
Lead arsenate	$PbHAsO_4$	43[2]	10
Check (no treatment)	—	91[2]	0

[1] Average of 2 tests.
[2] Average of 3 tests.

The toxicity tests were made in the laboratory by the apple-plug method, using from 79 to 105 plugs to a test. Each plug was infested with a single ready-to-hatch codling moth egg. The apple plugs were sprayed with the compounds at the rate of 4 pounds to 100 gallons of 20 per cent ethanol.

The results are given in table 1. N-*p*-tolylglycinonitrile and *o*-hydroxy-alpha-(1-piperidyl)-alpha-tolunitrile were more toxic and the rest of the compounds were less toxic than lead arsenate.

A small-scale foliage test of N-*p*-tolylglycinonitrile on a Stayman apple tree and an Elberta peach tree was made with a hand spray pump. No injury occurred on the apple foliage, but the peach foliage was severely damaged.

Insects Found on Guayule in Northern Mexico

VAN E. ROMNEY, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

A survey was made of insects attacking native and cultivated guayule, *Parthenium argentatum* Gray, within its natural habitat in northern Mexico from June 14 to 23, 1945.

Lloyd (1911) reported several insects attacking the shrub while a study was made of the plant at Cedros, Zacatecas, in 1907–8. He reported the root system to be infested with two scales, *Ceroputo yuccae* (Coq.) and *Orthezia* sp.; also a scale, *Targionia dearnessi* Ckll., was found on roots of field plants. The guayule borer, *Pityophthorus nigricans* Bland., was reported tunneling beneath the cortex of a harvested shrub.

During the above-mentioned survey the following insects and conditions were encountered on native and cultivated guayule shrubs in Mexico:

SCALES.—Two root scales were found on the native shrub. *Targionia* sp. (close to *dearnessi* Ckll.) was abundant at Rancho San Jose (10 miles east of Saltillo, Coahuila); this scale was also found 17½ miles west and 35 miles northwest of Cedros, Zaca-

tecas, 3 miles north of Tecolote, Coahuila, and on baled shrub at the Parras and Torreon rubber mills. *Targionia yuccarum* (Ckll.) was very abundant on roots at Rancho San Jose, 22.5 and 35 miles northwest of Cedros, Zacatecas, and 10 niles north of Tecolote, Coahuila, and on baled shrubs at Camacho, Zacatecas. These two root scales were widely distributed and played an important role in stunting the plants that were heavily infested. Only a few cultivated plants were examined for root scales, and none were found on them.

Two branch scales were also common on the native shrub. *Lecaniodiaspis* sp. (probably a new species) was very abundant at Rancho San Jose. In this location about half the specimens contained parasite exit holes, but there were no parasites present at the time. This scale was found frequently 6 miles west of Saltillo, Coahuila, 3 miles north of Tecolote, Coahuila, and on baled shrub from Nuevo Yucatan. *Tachardiella cornuta* (Ckll.) was noted at Rancho San Jose, 20¼ miles northwest of Cedros, Zacatecas, and on baled shrubs at the Cedros and Torreon rubber mills. These branch scales were abundant enough on certain branches to interfere with growth. None were found on cultivated guayule.

BEETLES.—Adults and larvae of *Pityophthorus mexicanus* Blkm. were common in stored baled shrubs at the Torreon and Parras rubber mills. This species may be the same as *nigricans* Bland. as reported by Lloyd. Larvae of *Urilleta* sp. (Anobiidae) were found tunneling the branch tissues of newly baled shrub at Torreon and Parras, Coahuila. Two buprestid larvae, *Chalcophora* sp. and *Dicerca* sp., were found burrowing in native baled shrubs at the Torreon rubber mill.

MOTHS.—Larvae of *Eucosma* sp. (Olethreutidae) were found to bore down the roots of native shrubs. The larvae fed on the live root tissues and apparently weakened the plants attacked but did not kill them. This insect was common at Rancho San Jose and could be found occasionally at the Torreon mill in baled shrubs from Nuevo Yucatan. Larvae of a plume moth were common as leaf feeders. They were abundant at Cedros, Zacatecas, on cultivated shrubs and at points west on wild shrubs.

MEALYBUGS.—A small dark-colored mealybug (Pseudococcini) was found reproducing in the growing tips of wild guayule shrubs and stunting their growth. The insect was found at Rancho San Jose and on baled native shrubs at the Torreon mill. Another species of mealybug was noted on the roots 10 miles north Tecolote, Coahuila, and at Rancho San Jose, but this insect was rare and specimens were not identified.

GRASSHOPPERS.—*Encoptolophus pallidus* Brun., *Platylactisca azteca* Gurney (Sauss.) and *Trachyrhachys kiowa* (Theo.) were collected from a plot of cultivated shrub near Monterrey, Nuevo Leon.

PLANT BUGS.—*Lygus* bugs were rare on guayule flowers in Mexico during June 1945. A few specimens of *Lygus oblineatus* (Say) were found on nursery plants near Torreon, Coahuila. In the same location *Polymerus basilis* (Reuter) was abundant.

LEAFHOPPERS.—*Cloanthanus heldoranus* (Ball) was common on both cultivated and native guayule in Mexico. Two species of *Empoasca* were common in cultivated plots at Parras, and Cartagena, Coahuila.

FULGORID.—*Hysteropterum sepulchralis* Ball was reproducing on wild shrubs rather generally throughout the areas surveyed.

Identifications of the above-mentioned insects were made by Harold Morrison, W. H. Anderson, Carl Heinrich, H. K. Townes, R. I. Sailer, and J. S. Caldwell, all of the Division of Insect Identification of this Bureau.

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Vegetable Weevil Parasites from South America and Their Colonization in California

HAROLD COMPERE, *Riverside, California*

The importation from South America of parasites of the vegetable weevil, *Listroderes obliquus* Klug, and their colonization in California is a cooperative project of the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, and the University of California Citrus Experiment Station. The parasites were collected in Argentina and Uruguay by Dr. H. L. Parker of the Bureau and colonized in California by the University. Four species which attack the vegetable weevil in its larval stages have been released in California, namely, the dipterous parasite, *Epiplagiops littoralis* Blanchard, and the hymenopterous parasites, *Porizon parkeri* Blanchard, *P. argentinensis* Blanchard and an identified species of *Triaspis*.

The introduction of parasites of an insect such as the vegetable weevil from the southern to the northern hemisphere is complicated by several factors. The vegetable weevil has only one generation annually, and its life cycle is synchronized with the seasons of the year. During the greater part of its adult life the weevil is in a summer diapause. At the time when the weevil is in the summer diapause in the southern hemisphere, it is in the active adult, egg, larval and pupal stages in the northern hemisphere. Likewise, the life cycles of its hymenopterous parasites are synchronized with the seasons. The parasites were collected in Argentina and Uruguay in the late winter or early spring in the months of September and October. Several weeks after collection and shipment the parasites arrived in California. The great majority of them were in the beginning phases of the summer diapause. September, October, and November mark the end of summer and the beginning of winter in California, the time when the parasites should be coming out instead of entering the diapause. In California the vegetable weevils become active about the middle of October and commence to reproduce about the first of November and continue until late spring. The reproductive period ends about the latter part of April or early May. During this period, when the host insect in California is in its larval stages, the great majority of the hymenopterous parasites remained in the summer diapause.

The two species of *Porison* which were introduced from South America are very closely related and are distinguished on the basis of a slight difference in color. Parker shipped to Riverside approximately 12,587 cocoons and 73 adults of *Porison*. These arrived during October, November and December, during the years 1942 to 1945. From these cocoons approximately 800 *Porizon* issued during the winter

months in California when host larvae were available. Before being released in the infested orchards and fields, the *Porizon* were mated and allowed to oviposit in a total of 3112 larvae under insectary conditions. A number of these (1271) were released in fields and orchards where food was abundant during the 1945–46 season. The remainder of the parasitized larvae were retained in an attempt to propagate another generation of parasites.

Unlike the hymenopterous parasites which arrived in Riverside in a state of diapause, the dipterous parasites, *Epiplagiops* issued as adults en route or shortly after arrival. Parker shipped to Riverside approximately 2000 *Epiplagiops* either as adults or puparia. The greater number of these died before vegetable weevil larvae were obtainable in California in late November and early December. The flies which survived until December reproduced in the insectary when provided with host larvae. A total of 7319 adult *Epiplagiops* were released in California where the vegetable weevil was most abundant. Each of the colonies released numbered from 30 to 500 flies. The greatest number were liberated in Orange and Los Angeles counties during the winter of 1943–44. In addition to the adult *Epiplagiops* which were released, the species was also colonized in the egg and larval stages. So far no recoveries of this species have been made.

In the insectary at Riverside, *Epiplagiops* reproduced generation after generation as long as larvae of the vegetable weevil were obtainable. The means by which this parasite survives during the summer months when all vegetable weevils are in the adult stage and immune to attack is not known.

An unidentified species of *Triaspis* was received in limited numbers from Parker. A few *Triaspis* issued as adults enroute. These readily oviposited in larvae of the vegetable weevil. Dissections of larvae which had been attacked revealed the parasite had deposited eggs and that these hatched and the larvae developed. At a later day an inspection revealed cocoons formed by the *Triaspis* larvae. The few cocoons that were formed contained dead pupae or prepupae. A small number of adult *Triaspis* were released in an infested orchard in Ventura County.

Dr. H. L. Parker plans to publish on the biologies of the parasite mentioned in this note.—6-3-46.

Comparative Toxicity of *p,p'*- and *o,p'*- DDT to Larvae of *Anopheles quadrimaculatus*

HOWARD A. JONES,[1] HARRY H. INCHO,[2] and CHRISTIAN C. DEONIER, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[3]

The major impurity occuring in technical DDT is the *o,p'*-isomer (1-trichloro-2-(*p*-chlorophenyl)-2-(*o*-chlorophenyl)ethane) (Haller *et al.* 1945). C. C. Deonier and coworkers at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine have shown that *o,p'*-DDT is less toxic than *p,p'*-DDT to fourth-instar larvae of *Anopheles quadrimaculatus* Say. Therefore, the comparative toxicity of these two isomers and mixtures of them has been of considerable interest.

Table 1.—Comparative toxicity of *p,p'*- and *o,p'*-DDT to fourth-instar larvae of *Anopheles quadrimaculatus*. (10 replications.)

Treatment	Concentration (p.p.m.)	Average Per Cent Mortality in 24 Hours	Average Per Cent Mortality in 48 Hours
o,p'-DDT[1]	.03	40.6	58.6
	.02	19.0	34.8
	.01	4.2	10.7
	.005	1.0	3.5
o,p'-DDT 75 per cent, *p,p'*-DDT 25 per cent	.01	33.4	57.2
	.0075	15.4	28.3
	.005	4.0	11.0
o,p'-DDT 50 per cent, *p,p'*-DDT 50 per cent	.01	71.5	84.5
	.0075	51.2	63.8
	.005	24.3	37.2
	.0025	3.5	12.1
o,p'-DDT 25 per cent, *p,p'*-DDT 75 per cent	.01	85.0	89.0
	.0075	69.6	80.8
	.005	30.0	41.8
	.0025[2]	2.0	3.9
	.00125[2]	0	3.4
p,p'-DDT[3]	.01	94.2	97.4
	.005	44.7	55.3
	.0025	9.3	15.6
	.00125	4.6	12.9

[1] Pure, synthetic compound furnished by S. J. Cristol, of this Bureau.
[2] Average of 8 replications.
[3] Prepared from technical DDT by recrystallizing twice from ethyl alcohol.

To determine the reduction in effectiveness of DDT when various proportions of the *o,p'*-isomer are present, tests were made in which acetone-water suspensions of both *o,p'*-DDT and *p,p'*-DDT were compared with mixtures containing 25–75, 50–50, and 75–25 parts by weight of these two pure compounds. For each test 20 fourth-instar larvae of *Anopheles quadrimaculatus* were placed in a beaker containing 250 ml. of distilled water and the material to be tested. Observations of larval mortality after 24 and 48 hours are shown in table 1.

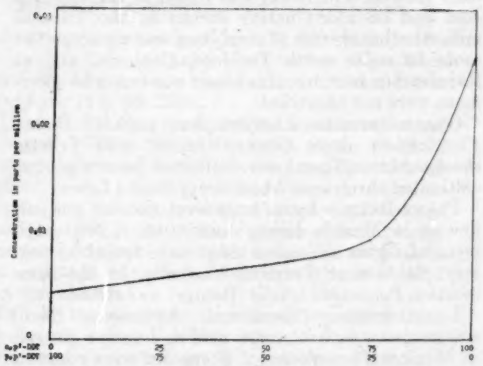

FIG. 1.—Concentrations of *o,p'*-DDT and *p,p'*-DDT, and of several mixtures of these materials, required to give 50 per cent kill of fourth-instar larvae of *Anopheles quadrimaculatus*.

[1] Now with the Unit of Entomological Research of Dodge & Olcott, Inc., Baltimore, Maryland.
[2] Sergeant, AUS, assigned from Army Air Forces Committee on Aerial Dispersal of Insecticides, located at Army Air Forces Center, Orlando, Fla.
[3] This work was conducted under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development, and from the Office of the Surgeon General, U. S. Army, to the Bureau of Entomology and Plant Quarantine.

The concentration of *o,p'*-DDT or *p,p'*-DDT required to give 50-per cent mortality in 48 hours was obtained graphically by plotting the various concentrations of each material against the mortalities. For the mortalities near 50 per cent a practically straight line was obtained. The *o,p'*-DDT required a concentration of 0.0263 p.p.m. to give a 50-per cent kill, whereas the *p,p'*-DDT required only 0.0045 p.p.m., indicating the latter to be about 6 times as toxic as the former.

In figure 1 the concentration required to give 50-per cent mortalityof *Anopheles quadrimaculatus* larvae in 48 hours has been plotted against the proportion of *p,p'*-DDT and *o,p'*-DDT in the materials tested. From this graph it is possible to determine for any mixture of the two pure materials the concentration that will give 50-per cent mortality in 48 hours. Technical DDT contains, in addition to *o,p'*-DDT, small amounts of a number of other substances (Haller *et al.* 1945), which also influence the toxicity of the product.—6-20-46.

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Toxicity of Nicotine, Nornicotine, and Anabasine to Codling Moth Larvae

E. H. SIEGLER and C. V. BOWEN, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

The close relationship of nornicotine and anabasine to nicotine in chemical structure and physiological behavior and their presence in species of *Nicotiana* make comparative toxicity tests against various insects desirable. Nornicotine occurs with nicotine in tobacco. Anabasine occurs in *Nicotiana glauca*, a plant that grows wild in the southwestern part of the United States, where it is commonly known as tree tobacco; it is also found in the Russian plant *Anabasis aphylla*. Anabasine sulfate has been used commercially as an insecticide in Russia, and at intervals during the last 10 or 12 years small quantities have been imported into the United States. This commercial product also contains other alkaloids which occur in *A. aphylla*. Insecticides containing mixtures of nicotine and anabasine have also been imported from Russia.

Richardson, *et al.* (1936) and Hansberry & Norton (1940) made toxicity studies of a number of alkaloids against *Aphis rumicis* L.

Richardson *et al.*, however, did not test *l*-beta-nornicotine, the isomeric form common to tobacco, but found anabasine to be the most toxic of the materials tested. Hansberry and Norton compared various isomeric nicotines and nornicotines and found the nornicotine common to tobacco to be more toxic than *l*-nicotine.

Harman (1934) tested anabasine sulfate against the codling moth, *Carpocapsa pomonella* (L.), in an orchard of King apples. He used lead arsenate (3 pounds per 100 gallons) in the first cover spray, followed by anabasine sulfate and oil (1 pint and 3 quarts, respectively, per 100 gallons) in four subsequent sprays. The same quantity of nicotine sulfate and oil was also tested in like manner. His data for wormy fruit show that the anabasine-oil treatment was much less effective than nicotine-oil. Nevskii *et al.* (1937) reported both nicotine sulfate and anabasine sulfate as ineffective against the codling moth when used alone, but as increasing the effectiveness of arsenical sprays to which they were added.

Table 1.—Toxicity to codling moth larvae of nicotine, nornicotine, and anabasine in comparison with DDT and lead arsenate.

COMPOUND	APPLE PLUGS	
	Wormy	Stung
	Per cent	
Nicotine	6	0
	14	3
	26	9
	Av. 16	4
Nornicotine	77	3
	85	0
	85	1
	Av. 83	1
Anabasine	71	1
	92	0
	93	1
	Av. 85	1
DDT	40	29
	57	13
	59	16
	Av. 52	20
Lead arsenate:		
Test 1	76	11
Test 2	60	1
	65	5
	65	7
	Av. 63	5
Check (no treatment)	89	0
	94	0
	Av. 92	0

The present study is concerned with the toxicity to codling moth larvae of aqueous solutions of the three alkaloids. After treatment of the nicotine with nitrous acid, and steam distillation of an alkaline solution to remove nornicotine and other secondary amines, an analysis (Bowen & Barthel 1943) was made in which it was found that the purification was complete. The nornicotine from low-nicotine tobacco was freed of nicotine, according to the method described by Smith (1942), and no test for an alkaloid was obtained in the steam distillate after nitrosation. The picrate melted at 190–191°C. and the alkaloid was methylated, forming nicotine. The anabasine was obtained from *Nicotiana glauca* Grah. and formed a picrate melting at 212–213° C. No alkaloids volatile with steam after nitrosation were present, and the alkaloid was methylated to methylanabasine, which formed a picrate melting at 236–237° C.

The alkaloids were tested in aqueous solution at a concentration of 0.05 per cent. A suspension of DDT (technical) at the same concentration, obtained by adding 4 parts of water to 1 part of an alcoholic

solution of DDT, was compared with the alkaloids. Lead arsenate (4 pounds per 100 gallons) was also used. In test 1 the carrier consisted of water 80 per cent plus ethanol (95 per cent) 20 per cent by volume; in test 2, which consisted of 3 replicates, the carrier for lead arsenate was water. The toxicity tests were made by the apple-plug method, one ready-to-hatch codling moth egg being used for each plug. From 81 to 106 apple plugs were used in each test.

The results of the tests are given in table 1. The most effective compound was nicotine, which was considerably more toxic than any of the others. The DDT suspension was next in effectiveness. Nornicotine and anabasine were still less effective and were about equal in their toxicities. Lead arsenate was better than nornicotine and anabasine, but not so good as DDT. In this connection, however, it should be kept in mind that the dosage of lead arsenate was 10 times that of the other compounds tested.—8-16-46.

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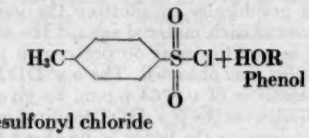
Toxicity of Aromatic Esters of *p*-Toluenesulfonic Acid to Codling Moth Larvae

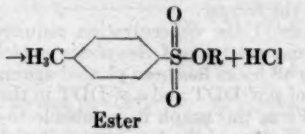
E. H. SIEGLER and S. I. GERTLER, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

This paper presents the results obtained in laboratory tests of certain aromatic esters of *p*-toluenesulfonic acid against larvae of the codling moth, *Carpocapsa pomonella* (L.).

The esters of *p*-toluenesulfonic acid were prepared by the reaction of *p*-toluenesulfonyl chloride with the appropriate phenols, making use of the Schotten-Baumann method. The following equation is typical of the reaction:



p-Toluenesulfonyl chloride



Ester

All tests were made by the apple-plug method (Siegler *et al.* 1934), about 100 plugs being used for each organic compound and 200 each for the lead arsenate and check tests. Each plug was infested with a single ready-to-hatch codling moth egg.

The compounds were used at the rate of 4 pounds to 100 gallons of carrier, which consisted of ethanol (95 per cent) 20 per cent and water 80 per cent.

Table 1.—Toxicity of some aromatic esters of *p*-toluenesulfonic acid to codling moth larvae.

Ester	Formula	Percentage of Apple Plugs	
		Wormy	Stung
2-Naphthyl	$CH_3C_6H_4SO_3C_{10}H_7$	76	2
p-Tolyl	$CH_3C_6H_4SO_3C_6H_4CH_3$	78	1
p-Nitrophenyl	$CH_3C_6H_4SO_3C_6H_4NO_2$	90	0
1-Naphthyl	$CH_3C_6H_4SO_3C_{10}H_7$	91	1
p-Nitrophenyl	$CH_3C_6H_4SO_3C_6H_4NO_2$	93	1
o-Nitrophenyl	$CH_3C_6H_4SO_3C_6H_4NO_2$	94	0
m-Tolyl	$CH_3C_6H_4SO_3C_6H_4CH_3$	94	2
Checks:			
Lead arsenate	$PbHAsO_4$	56	10
Untreated		86	2

The results, which are given in table 1, show that these esters of *p*-toluenesulfonic acid were considerably less toxic than lead arsenate and do not appear to offer promise as insecticides for the codling moth.

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Effect of DDT, Xanthone, and Nicotine Bentonite on the Woolly Apple Aphid

E. J. NEWCOMER, F. P. DEAN, and F. W. CARLSON, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

In testing new materials for controlling the codling moth, *Carpocapsa pomonella* (L.), it is important to observe the effect such materials may have on other pests of the apple tree. The woolly apple aphid, *Eriosoma lanigerum* Hausm., was formerly a rather serious pest in the Pacific Northwest, but since the introduction of the parasite *Aphelinus mali* (Hald.) (Newcomer 1940) it has become relatively insignificant, although some woolly aphids can usually be found in almost any orchard.

It is particularly important in the case of this insect, then, to determine whether this natural balance is in any way disturbed by the use of new insecticides.

In the fall of 1944, at Yakima, Wash., a very heavy infestation of the woolly apple aphid developed in most of the trees that had been sprayed experimentally with DDT. Evidently the DDT sprayed on the trees interfered with the normal activity of the parasites, although some parasitism took place in these trees. In September a measure of this infestation was taken by determining the percentage of nodes, or leaf insertions, on the new growth and water sprouts that had colonies of woolly aphids.[1] Of 1200 nodes examined on 3 trees that had been sprayed 6 times with DDT at 8 ounces to 100 gallons, 31 per cent were infested. Of 1200 nodes on 3 trees nearby that had been sprayed 6 times with lead arsenate at 3 pounds to 100 gallons, only 9.5 per cent were infested. The colonies on the trees sprayed with DDT usually consisted of many live aphids, but the colonies on the trees sprayed with lead arsenate consisted of only a few, many of which had been parasitized.

In 1945 a much more thorough record was made of the infestation of woolly aphids in trees sprayed with various materials, including DDT, nicotine bentonite, and xanthone, with lead arsenate used as a standard. Most of the treatments were included in both experimental plots in a Rome orchard and one in a Winesap orchard, the Romes being sprayed with a calyx and six cover applications and the Winesaps with a calyx and seven cover applications. The calyx spray in every instance consisted of 2 pounds of lead arsenate to 100 gallons, and the other materials were used in the cover sprays. As there were eight trees in each treatment in each of the three replications, only 200 nodes per tree, or a total of 4800 nodes for each treatment, were examined. The percentages of infested nodes found are shown in table 1.

[1] Suggested by Leroy Childs, superintendent, Hood River Branch Experiment Station, Hood River, Ore.

The addition of DDT to another insecticide always resulted in an increased infestation of woolly aphids in the trees where the combinations were used. DDT used alone in the Rome A orchard resulted in a still heavier infestation. As in 1944, the individual colonies usually were larger and there was less parasitism where DDT was used than where it was not used. A check on parasitization by *Aphelinus* was obtained several times late in July. In treatment 1 the parasitization at that time was about 45 per cent, in treatment 3 it was about 30 per cent, and in another treatment similar to 3 it was about 22 per cent.

Nicotine bentonite evidently has a definite effect on the woolly apple aphid, as the infestation in trees sprayed with this material (treatment 4) was much less than in trees sprayed with lead arsenate. But when DDT was added to half-strength nicotine bentonite (treatment 5) the infestation was greatly increased.

The extremely low infestations in the trees sprayed with xanthone (treatments 6 and 7) are of particular interest. No doubt some of this control was brought about by the use of nicotine bentonite in the first two cover sprays. However, the infestation in the trees sprayed throughout the season with nicotine bentonite, while low, was 6 to 20 times that in the trees sprayed for the rest of the season with xanthone, which is evidence that the xanthone had a greater effect on the woolly aphids than did the nicotine. This effect has also been noted in California by Borden (1944), who stated that "less woolly apple aphid occurred in and on apple in the Watsonville area where xanthone had been used."

In the fall of 1945 a small test was made to deter-

Table 1.—Infestations of woolly apple aphid resulting from successive applications of DDT, xanthone, nicotine bentonite, and lead arsenate.

Treatment	Treatment (Quantity Per 100 Gal.)	Leaf Nodes Infested with Woolly Apple Aphids		
		Rome A	Rome B	Winesap
		Per cent	*Per cent*	*Per cent*
1	Lead arsenate 3 lb., emulsible mineral oil 1 qt.,[1] colloidal spreader 2.67 oz.	10.0	8.6	11.1
2	Lead arsenate 1.5 lb., DDT 4 oz., emulsible mineral oil 1 qt.,[1] colloidal spreader 2.67 oz.	12.0	20.1	33.4
3	DDT 8 oz., pyrophyllite 1.5 lb.	16.9	—	—
4	Nicotine bentonite (commercial, 14% nicotine) 2 lb., mineral oil 1 qt.,[1] oleic acid 4 oz., aluminum sulfate 2 oz.	1.9	2.1	3.1
5	Nicotine bentonite (commercial, 14% nicotine) 1 lb., DDT 4 oz., mineral oil 1 qt.,[1] oleic acid 4 oz., aluminum sulfate 2 oz.	12.0	—	—
6	Xanthone 2 lb., stove oil 1 qt., colloidal spreader 8 oz. (commercial nicotine bentonite as in (4) 1st and 2d cover sprays)	0.3	0.1	0.5
7	Xanthone 1 lb., DDT 4 oz., stove oil 1 qt., colloidal spreader 8 oz. (commercial nicotine bentonite as in (4) 1st and 2d cover sprays)	1.8	1.9	4.4

[1] Increased to 2 qt. in 2 or 3 cover sprays.

mine whether xanthone or the stove oil used with it killed the woolly aphids at the time of application. On September 28 twigs heavily infested with aphids were thoroughly sprayed with the xanthone used in treatment 6 (Table 1). Other twigs were similarly sprayed, except that in one test the xanthone was omitted and in another test the stove oil was omitted. Although the aphids had been thoroughly wetted by these sprays, no mortality resulted. On October 23 the same twigs were again sprayed with the same mixtures. Ten days later there had been no mortality. While it is possible that xanthone would kill woolly aphids in hot weather, it seems more probable that in some way it prevents the young aphids from settling on the bark. Further work on this question is contemplated.

CONCLUSIONS.—The continued use of DDT on apple trees throughout a season in the Pacific Northwest results in greatly increased infestations of the woolly apple aphid, apparently by interfering with the normal activity of the *Aphelinus* parasite. These observations were made on trees scattered about an orchard which also contained many trees not sprayed with DDT. Many of the woolly aphids developing on trees sprayed with DDT were therefore parasitized by *Aphelinus* flying from other trees between sprays. It would be logical to assume that if a large orchard were sprayed with DDT the woolly aphids would become even more numerous in it, since there would be no near by source of parasites. Probably special control measures would have to be taken.

Nicotine bentonite definitely reduces the numbers of woolly aphids when used periodically during the season, and they would not be a problem if it were used.

Xanthone resulted in the lowest infestation of any of the materials used, and it evidently has a greater effect on the aphids than nicotine bentonite, although there is no evidence that it directly kills them. They simply do not develop on trees so sprayed, and this would be a distinct advantage if xanthone were to be used. Even if some DDT is used with the xanthone, the infestation still remains at a very low level.

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DDT to Control *Mezium americanum*

EUGENE J. GERBERG, *Baltimore 7, Maryland*

A number of red spider bettles, *Mezium americanum* Laporte, were found in a large baking establishment. These small, dark red, spider-like insects were living in cracks and accumulated dirt. They are said to be scavengers, however, to comply with food and drug laws, all insects must be eliminated from the premises. They were most abundant in the receiving department and basement storage room. In order to prevent contamination of foodstuffs by insect infestations, a thorough residual spray program was inaugurated. All walls, beams and studs were thoroughly sprayed with a 4 per cent DDT solution. The carrier and solvent used was a highly refined hydrocarbon distillate, thus eliminating contaminating odors and unsightly stains. A 3-gallon *Lofstrand* hand pressure sprayer with a flat spray nozzle was used to apply the residual spray. Five days after the area was treated, an examination revealed dead spider beetles in numbers. The kill was quite spectacular as there were comparatively few beetles in evidence at the time of spraying. It is apparent that they and the many other insects found dead and dying were affected by the DDT residue. This is an efficient and economical means of reducing insect infestations in bakeries and warehouses.—6-25-46.

Grasshopper Control by Oil Solutions of DNOC Sprayed from Aircraft

A. W. A. BROWN[1] and L. G. PUTNAM[2]

The following is a report of an attempt to control a grasshopper infestation on farm land with an oil solution of *DNOC* emitted from a high-speed high-capacity aircraft. Promising results having been obtained in the laboratory and on artificial field layouts, an operational trial was carried out in a heavy infestation of *Melanoplus m. mexicanus* Sauss, in summer-fallow covered with Russian thistle and pigweed at Majorville, near Bassano, Alberta.

The aircraft employed was the *Mitchell III* (*B-25 J*) bomber, flying at 200 m.p.h. approximately 150 feet above terrain. A 10 per cent *DNOC* in oil solution was emitted from the 279-gallon lower auxiliary fuel tank at 3.5 gallons per second from a 4-inch vertical emission pipe. A strip field 1 mile long and 220 yards wide was covered by 3 emission runs of the aircraft.

The aircraft tank was charged with 1700 lbs. of a 10 per cent (wt/wt) solution of *DNOC* commercial grade (Standard Agricultural Chemicals) in a mixture of 1 part xylene to 3 parts *Diol 40* (a heavy fuel oil). Approximately 0.5 per cent of *Williams Red* dye was added to permit colorimetric assessment of the spray deposit to be made. The specific gravity of the solution was 0.922, and its viscosity 41.0 centipoise (at 25° C.). It had been found in a previous trial that the mass median diameter of droplets emitted by this method was approximately 360 microns (0.36 mm.).

The following procedure was employed in assessing the percentage mortality of the grasshopper population resulting from the spray. Four hours before the trial, visual estimates of the population per square yard were made every 10 yards in 40 rows running across the field, the rows being 40 yards apart. The average population over the whole area, based on these 800 individual estimates, was 7.02 per square yard. The morning following the trial (carried out at evening) a visual estimate was made of the surviving population by the same method and at roughly the same points at which the original population was estimated. In addition, a count of dead and affected grasshoppers was made on a square yard of ground at each of 161 sampling points evenly spaced on lines running across the field.

For colorimetric assessment of the spray deposit,

[1] Experimental Station, Suffield, Alberta (Department of National Defence, Canda).
[2] Dominion Entomological Laboratory, Brandon, Manitoba (Department of Agriculture, Canada).

7 lines of sampling points were laid across the field, with 23 sampling points located along each line at 10-yard intervals, and at each point was placed a "jump-card" (18-inch square white cardboard) with a 4-inch petri dish on it. It was at these sampling points that the counts of dead on the ground were subsequently made. In this way the distribution of the spray could be plotted, and a correlation could be made between deposit density and kill, bearing in mind the distribution of the original population.

The spraying operation was carried out between 5.50 and 6.20 p.m., under conditions of slight lapse (upward convection), the wind ratio (calculated from the temperature gradient) being 1.10. The wind was light, 3 to 6 m.p.h., varying from W to N.W. The aircraft flew on tracks parallel to the length of the field from W to E, each track being downwind of the preceding one. The first track was 10 yards upwind of the upwind margin of the field, the second 75 yards downwind of the upwind margin, and the third 150 yards downwind of the upwind margin. The height of the first run was 90 feet, and of the second and third runs 170 feet above terrain. It should be emphasized that the height and location of each run was determined in view of meteorological conditions at the moment, and the instructions were relayed to the pilot by radio from the ground.

The coverage of the spray over the field, as measured by the spot deposit densities on the petri dishes, was reasonably even, all sampling points showing some degree of deposit, and no spot deposits exceeding 3.5 lbs. per acre. The average spot deposit figure was 1.08 lbs. per acre. (The first 100 yards of the field was not hit in all the runs due to late opening of the emission valve in the aircraft, and that row of sampling points is omitted from consideration.) The proportion of material emitted that was recovered on the field was 58 per cent. The amount of spray expended in the operation was 1311 lbs., containing 131 lbs. *DNOC*, over the 80-acre field, representing an average overall expenditure of 1.64 lbs. per acre.

The average population of live grasshoppers remaining on the field the following morning, using the same method as for the original estimate, was found to be 2.00 per square yard over the whole field, or 1.67 per square yard omitting the first 100 yards, representing a population reduction of 5.35 per square yard or 76 per cent. The average number of dead grasshoppers found on the ground was 5.56 per square yard, and the number of definitely affected (characterized by uncoordinated movements, lack of balance, and inability to fly normally) individuals was 1.47 per square yard. It is probable that a proportion of these individuals was included in the estimate of the surviving population.

The effect of *DNOC* on the vegetation was observed from a previous spray trial, where heavy dosages were put down in narrow swaths. No burning of foliage of Russian thistle and pigweed was noted until the area deposit exceeded a figure between 5 and 10 lbs. per acre.

In a field trial carried out at Suffield, Alberta, using grasshoppers exposed on jump-cards on the layout, a single emission run of the *Mitchell II* aircraft emitting a 10 per cent *DNOC* in oil spray caused 100 per cent mortality of *Melanoplus mexicanus* over a swath varying from 30 to 80 yards in width.

In a preliminary trial on farm land at Majorville, where the *Mitchell III* aircraft made two parallel emission runs over a similar 80-acre field at the very low altitude of 50 feet, so that the swathes were dense and narrow, a 44 per cent reduction was obtained in a population of *Melanoplus mexicanus* originally estimated at 15.8 per square yard.

Detailed examination of aircraft spray data, combined with aerosol generator and laboratory spray results, would indicate that more than 90 per cent control could be expected if *all* points in the area were covered at a rate of more than 0.3 lbs. per acre, and 100 per cent control if the rate were greater than 0.5 lbs. *DNOC* in oil solution per acre.

SUMMARY.—A spray of 10 per cent *DNOC* in oil solution, emitted to the extent of 131 lbs. of *DNOC* from a *Mitchell III* aircraft in 3 parallel emission runs over an 80-acre field, 1 mile long by 220 yards wide, exhibiting a heavy infestation of *Melanoplus mexicanus* in Russian thistle and pigweed vegetation, caused a population reduction of between 71 and 76 per cent.[1]—6-29-46.

[1] The field trials were carried out by the Experimental Station, Suffield, in cooperation with the Division of Entomology, Dominion Department of Agriculture. Biological assessments were made with the assistance of Mr. G. F. Manson, Officer-in-charge, Dominion Entomological Laboratory, Lethbridge; the original programme of these trials was drawn up with the collaboration of Dr. R. H. Handford, Grasshopper Research Leader for the Prairie Provinces.

Grasshopper Control in Alfalfa with Hexachlorocyclohexane Dust

CHARLES H. BRETT and W. C. RHOADES[1]

Severe outbreaks of grasshoppers in alfalfa fields of northwestern Oklahoma afforded an opportunity to test the value of new insecticidal materials used as dusts. High temperatures in Oklahoma generally have complicated the effective use of baits, leaving much to be desired in practical control.

MATERIALS AND METHODS.—The most toxic preparation applied in these tests was a wettable powder containing 50 per cent technical hexachlorocyclohexane, 10 per cent of which was gamma isomer. Other dusts were prepared in a series of concentrations of the gamma isomer by diluting with talc a preparation which was 100 per cent technical hexachlorocyclohexane containing 10 per cent of the gamma isomer. A few tests were prepared by impregnating talc with technical *Velsicol 1068*.

Applications of these dusts were made with a *Root Model Y-2*, six-row power duster. This machine was mounted on a two-wheel trailer and drawn behind a light truck.

The dust for each treatment, except the wettable preparation, was applied at the rate of 10 pounds per acre over 2.5 acre plots. Treatments were made at three different times and in two different localities. The chart in figure 1 shows the averages of these tests.

In all plots the alfalfa was about 15 inches high and nearly ready to be cut. Grasshoppers were estimated to average between 35 and 40 insects per square yard. Severe damage had been done to the plants.

Records were made in the dusted plots between 6 to 8 hours after application and again between 24 to 30 hours after. A square yard frame was placed on the ground and two observers counted all af-

[1] Respectively, Assistant Entomologist and Research Assistant, Oklahoma Agricultural Experiment Station, Stillwater, Oklahoma.

fected and dead grasshoppers within this area. Such counts were replicated from 5 to 10 times in each plot.

During the tests, humidity averaged below 50 per cent with temperatures ranging from 80° to 95° F. The air was nearly quiet when dusts were applied.

RESULTS.—Grasshoppers showed symptoms of having been poisoned within a few minutes after dusts of the higher concentrations were applied. This time increased as the concentration decreased. Dust containing 0.1 per cent gamma isomer did not produce symptoms until after 4 hours. Characteristically the insects stumbled about, showing loss of coordination accompanied by peculiar nervous tremors similar to the effect of DDT on flies. This condition progressed to a point of complete inactivity, the rate of progress being determined by the concentration of gamma isomer as is shown in figure 1.

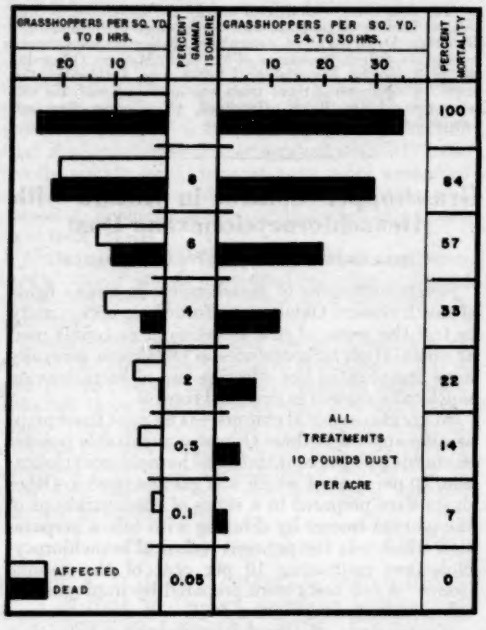

FIG. 1.—Grasshopper control in alfalfa. Top bars represent a test using wettable dust containing 50 per cent hexachlorocyclohexane of which 10 per cent was gamma isomer. The seven other concentrations shown were dilutions with talc of a technical concentrate containing 10 per cent gamma isomer.

After 24 hours all affected grasshoppers were either dead or had recovered. Of 200 affected grasshoppers collected at the end of 6 hours from plots treated with 2 per cent gamma isomer, 3 per cent had completely recovered at the end of 24 hours. Under cage conditions these fed and completed their development. Little residual effect of the poison could be seen under field conditions. Small plots dusted with the wettable dust containing 5 per cent gamma isomer, at the rate of 38 pounds per acre showed complete kill by the end of 6 hours. Grasshoppers subsequently moving into these plots were not affected. At the end of 2 weeks the population was restored. There was no evidence of phytotoxicity or continued poisoning of grasshoppers.

It is probable that different species vary in their susceptibility. No living lesser migratory grasshoppers, *Melanoplus mexicanus mexicanus* (Saussure), were collected from any of the plots above 0.5 per cent gamma isomer after 24 hours.

Grasshoppers present during the first tests were: *Melanoplus differentialis*, nymphs 87 per cent, adults 1.4 per cent; *M. bivittatus*, adults 0.6 per cent; and *M. mexicanus*, adults 11 per cent. Tests made 2 weeks later in a different area included: *M. differentialis*, nymphs 48 per cent, adults 6 per cent; *M. bivittatus*, nymphs 2 per cent, adults 10 per cent; and *M. mexicanus*, adults 10 per cent. Nymphs and adults were about equally susceptible to the poison. Preliminary tests have shown the use of synergic materials such as pyrethrins and piperonyl cyclohexanone to increase the percentage of grasshoppers killed with the lower concentrations of gamma isomer and to decrease the time of kill. Further experiments are planned in this regard.

Plots were dusted with *Velsicol 1068* in the same manner as those with hexachlorocyclohexane. No grasshoppers were affected or killed at concentrations of 0.05, 0.1, 0.5, or 1.0 per cent *Velsicol 1068*. Dust containing 5 per cent *Velsicol 1068* killed 1.3 grasshoppers per square yard or 3.7 per cent of the population. Ten per cent dust killed 2.7 grasshoppers per square yard or 7.7 per cent of the population.

Insects other than grasshoppers which were observed to have been killed in plots dusted with hexachlorocyclohexane included:

1. Plains false wireworm, *Eleodes opaca* (Say)
2. Imbricated snout beetle, *Epicaerus imbricatus* (Say)
3. Convergent lady beetle, *Hippodamia convergens* Guer.
4. Tiger beetle, *Cicindela punctulata* Oliv.
5. Ground beetles, Carabidae.
6. Camel crickets, *Udeopsylla* spp.
7. Red harvester ant, *Pogonomyrmex* sp.
8. Alfalfa caterpillar, *Colias philodice eurytheme* Bdv.
9. Garden webworm, *Loxostege similalis* (Guen)
10. Flies, Diptera.

The leafhoppers (Cicadellidae) were least affected of any insects which were present in numbers. Many of them survived. Hymenoptera were conspicuously absent from the plots.

DISCUSSION.—Hexachlorocyclohexane dust is an effective material for controlling grasshoppers. Its practicability depends upon the manufacture of refined material cheaply and in quantities. Its application on a large scale by means of power dusters or aeroplanes will bring a vast saving of seed alfalfa and other crops.

SUMMARY.—Tests in alfalfa fields with hexachlorocyclohexane gave good control of grasshoppers when dust containing 8 per cent gamma isomer was applied at the rate of 10 pounds per acre. When this concentration was reduced, control was proportionally less effective. There was a variation between different sample preparations. A wettable dust containing 5 per cent gamma isomer appeared to be about twice as toxic as a technical concentrate diluted with talc.

Grasshoppers not killed within 24 hours remained active. No residual or phytotoxic effects were apparent.

Velsicol 1068, as a 10 per cent technical material in talc, at 10 pounds per acre, was not satisfactory in controlling grasshoppers.—7-12-46.

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Hash and Rehash

IT IS TO BE assumed that there has been criticism of the editorial policies of the JOURNAL even though it is true that very little of such criticism has come to the attention of the editor. When the editor takes a realistic look at his own policies, and his actions in carrying them out, he is forced to admit that much criticism might fairly be aroused among both contributors and readers which he must recognize as just and well-deserved. The editor will venture to advance the opinion that, if he had better succeeded in realizing what he has attempted, in the way of editorial "meddling" and also, if the contributors were better informed as to his policies, the criticisms might be somewhat less severe. A discussion of policies may well be in order at this time.

The editor holds, first, that the JOURNAL is published for the good of the science and profession of entomology; that the good of the profession comes first; the interests of the readers are second but inseparable from the first consideration, and that the interests of the contributors come third. The latter should coincide with the others but do not always seem to do so.

The first consideration is the standing of the profession of entomology in the scientific world and in the world where cultural standards are considered. Too often members of the profession lose sight of the cultural considerations in their pursuit of the practical. A glance at the history, not of entomology but of entomologists, may throw some light on this point. Early entomologists were classically educated. They integrated the terminology of entomology with the classics and established for the science a firm cultural background. The first wave of economic entomologists retained the classical contacts; a study of the early publications in economic entomology affords irrefutable evidence of this statement.

Later, economic entomology became associated with Colleges of Agriculture where the trend was away from the cultural and stressed the immediately practical. Even in this environment entomologists clung to their standards until the inauguration of the extension movement. With that movement developed the idea that scientists writing for farmers must "write down" to the farmer, and that field men, talking to groups of farmers must "talk down" to the farmer. This was called "speaking the farmers' language" and the idea developed that it was necessary to present plain facts in kindergarten language or in the vernacular of the farm community to have it understood. The practice persists and may even be growing but is certainly based on a misconception of the farmer.

Extension men are often college teachers and research men and are so known to the farmers. Farmers are not the ignorant yokels the extension policy supposes. They listen with understanding to their preachers who use good, often classical, language. They read good newspapers and magazines in which high standards of English are maintained. They listen to the radio, but we hesitate to express our opinion as to the effect that may have on their cultural standards. At any rate, the farmer, regardless of his standards of spoken English, usually recognizes the English of the educated man as an evidence of his education. And it is our firm belief that the farmer wants his technical information in dignified and correct language. He does not want to be babied or to have his intelligence belittled.

The farmer does not want circulars on "Outwitting the Doodle-bug" or bearing similar titles childishly attributing human motives and human intelligence to the insects. And he does not have too much respect for the Extension Service which issues such publications.

And if the farmer discounts the entomologist because of such tactics what effect must these have on the better

educated communities? And how must the entomologist rate with other groups in the world of science?

Several years ago the late Dr. Frison, then editor of the JOURNAL, wrote an editorial entitled "Entomologists Don't Rate," in which he expressed the concern of the profession over the fact that entomologists were exceedingly scarce among the starred scientists in *American Men of Science*. Could one of the reasons for this condition be that entomologists and members of other groups which engage in extension work in agriculture, have deliberately, through much of their published work, belittled themselves, their ability and their cultural standards?

No one believes more firmly than the editor that the entomologists of this country are as broadly educated as any other group working in science. And that the average of ability in the group is not exceeded in other sciences. Men trained in entomology have developed into chemists whose work will compare favorably with that of chemists working in any other field; they have demonstrated an ability to apply mathematics in its more complicated forms in statistical analyses of their research data. They have mastered languages and certainly have as good a knowledge of their own language and how to use it, as any group. But, too often, they have come to discount the necessity of using technically correct language in all their publications.

Not only are JOURNAL articles often carelessly written, doubtless because pressure of other duties induces too much haste, but in many instances they follow the standards of the extension school, apparently deliberately. Only to a limited extent, and then with considerable trepidation, has the editor of the JOURNAL done anything about this matter. It is by no means clear to him that he is authorized to do anything; or that he has the ability to do what needs to be done.

However, at the moment, certain tendencies may be mentioned. They touch on one of the weaknesses of the editor—the matter of names. Too little constructive attention is being paid at the moment to securing adequate and *usable* names for the many new insecticides. In place of letting names for these substances creep into the literature we should adopt the rule of using no new name, other than the chemical designation of a new insecticide, without having suggested names considered and approved by the committee which now exists for that purpose. Prevent the establishment in the literature and in bibliographies, of names which will be found to be unsatisfactory. Literally dozens, perhaps hundreds of new materials, are coming into use. They have names which are often inconvenient and unsuitable on other grounds. Immediate constructive action is imperative if confusion in the future is to be avoided.

And, when names are being considered, unimportant as the matter may seem to some, the rules of language formation should receive due consideration.

In some popular publications in recent years terms such as "miticides" and even the terrible "loosicide" have been allowed to appear. This is defended on the grounds that they are for popular consumption. (And anything is good enough for the poor ignorant farmer.) But remember, that the reader is likely to judge our entomological ability, which he can not otherwise evaluate, by the evidence we show of good general education, which he can recognize, and to condemn us and doubt our recommendations just on the evidence which we place before him.

Neither of the words mentioned is necessary or defensible. Insecticide could be used as a substitute for either. It is true that mites are not insects but the substances used in their control are usually insecticides. And the Acarina are, in fact, an integral part of the science of entomology in its economic phrases. In addition, a word etymologically and phonetically satisfactory has already been used to designate mite-killing substances—"acaricides." Pediculicides, equally correct, is less satisfactory but infinitely preferable to "lousicide."

Both these terms have been barred, arbitrarily, from the JOURNAL. Other similar terms will be barred by the editor so long as he can get away with it. In this way he hopes that he may contribute a bit to the "rating" of entomologists in the cultural world and even enhance their influence with the "poor ignorant farmer." And while the writer has not had wide experience in extension work he will cite one fact which has impressed itself on his notice.

Almost invariably, when a farmer is visited and some insect is demonstrated to him in the field, he wants to *hear* the technical name of the insect. Partly through curiosity, doubtless. But also, partly, to assure himself that the extension man knows his business. So, if we want to show off, let us do it by stressing our knowledge, not of Mother Goose expressions, but of good technical entomology in good technical English—which must be good literary English.

OBITUARIES

Kennith Hawkins, 1890-1946

Kennith Hawkins died on Wednesday, October 9, 1946, at his home in Watertown, Wisconsin, from a heart attack. Mr. Hawkins had been in poor health for several years and had been obliged to reduce his activities to the minimum.

Mr. Hawkins was born in Plainfield, Illinois, on February 8, 1890. He was educated in the public schools of Plainfield and later was enrolled in Extension Classes of the University of Chicago at Joliet, Illinois. His early years were spent in newspaper and magazine work and he was, at one time, City Editor of a newspaper in Pensacola, Florida. He also, at different times, was on the staffs of *Town and Country*, *Country Gentleman* and *Farmers Review*.

He established himself in the employ of the G. B. Lewis Company, in Watertown, Wisconsin, in 1919 and served as general sales manager and was in charge of sales promotion and advertising for the company and won esteem as a business man and as an associate.

In this business connection Mr. Hawkins became an authority on bees and wrote *How to Succeed with Bees*, a book which enjoyed eleven editions, and *Beekeeping in the South*.

Hawkins had a wide acquaintance among beekeepers which promoted his acquaintance with entomologists and he was, for several years, a member of the Association. He was quiet in habit but impressed his associates by his outstanding characteristic which was a friendly interest in all his associates and an endearing personality which combined intelligence with a sense of humor and high ideals. Modesty and unfailing consideration for all with whom he came into contact were also notable qualities.

Even those whose only contacts with him were through correspondence and occasional contacts at meetings, share in the sense of personal loss which must be felt most keenly by his family and everyday associates.

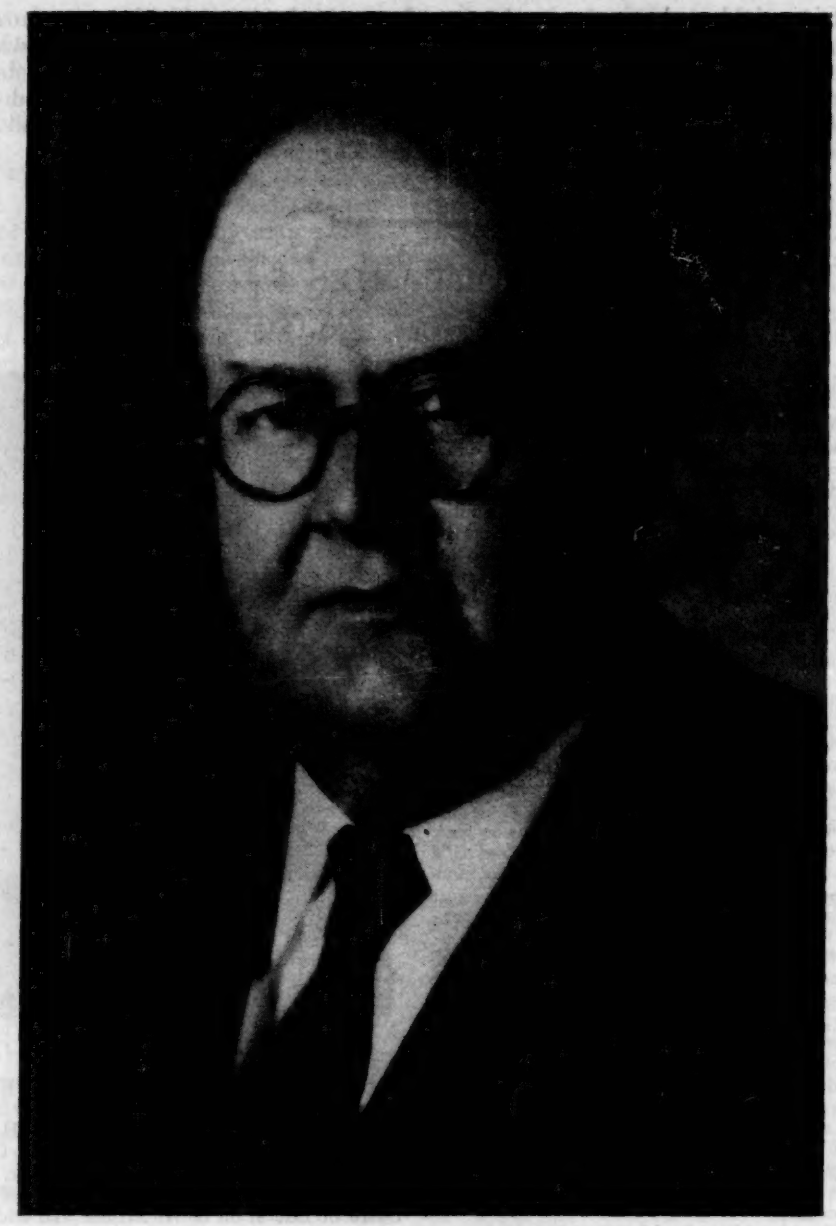
Mr. Hawkins is survived by his wife, the former Ella Clausing, to whom he was married in 1922, in Watertown, and three children: Mrs. Kenneth Rhodes of Milwaukee; Edgar Hawkins of Los Angeles and Paul Hawkins of Watertown. He was a Mason, a member of the Union League Club of Chicago, of the American Honey Institute, and of the De Molay council of advisers. He served on the Board of Education in Watertown and had many other affiliations which his failing health compelled him to relinquish in recent years.

Kennith Hawkins

Thomas J. Headlee

Doctor Thomas J. Headlee died on Friday, June 14th, 1946, at Muhlenburg Hospital, Plainfield, N. J. of complications following an operation. Doctor Headlee was long active in the American Association of Economic Entomologists and served as its President in 1929. Until his retirement from active duty two years ago, he was a faithful attendant of the meetings of the Association and of the Eastern Branch, which he helped organize and of which he was Chairman in 1933.

Doctor Headlee retired January 1st, 1944 as Professor of Entomology, Rutgers University, Entomologist of the New Jersey Agricultural Experiment Station and State Entomologist, after a period of



Thomas J. Headlee

service extending over 31 years. He was appointed Professor Emeritus of Entomology, Rutgers University, at his retirement from active duty. Before his appointment to the positions left vacant by the death of Doctor John B. Smith in 1912, Doctor Headlee was Professor of Zoology and Entomology and State Entomologist at the Kansas State College of Agriculture from 1907 to 1912. Previous to that he was Associate Entomologist at the New Hampshire Agricultural Experiment Station as an associate of the late E. Dwight Sanderson.

Doctor Headlee was born in the small community of Headlee, Indiana, of pioneer stock. Like many young men of that region and time he educated himself. He taught school for several years, beginning at the age of 18. He attended the University of Indiana where he graduated in 1903. Continuing in post graduate work he received the Degree of Master of Arts from the same institution in 1904. From Indiana he went to Cornell where he studied under Professor J. H. Comstock. He earned his Doctorate there in 1906.

The insect control problems which attracted Doctor Headlee's interest over a period of more than forty years was extremely varied in scope. Perhaps his most outstanding work was in the field of mosquito control. He was instrumental in the formation of the New Jersey Mosquito Extermination Association in 1914 and through his qualities of leadership made it an important and continuously active factor in the control of mosquitoes, a primary insect problem in New Jersey. His more than 30 years' work on mosquitoes was climaxed by the publication in 1945 of "The Mosquitoes of New Jersey and Their Control" which summarizes his laboratory and field work on these insects. Doctor Headlee was interested in Insect Physiology, particularly the response of insects to environmental factors, and was a pioneer in the study of radio and other waves on insects. He maintained at all times an active interest in the problems delegated for special study to members of his staff and his stimulating suggestions were responsible, to a large degree, for much of the progress made in a variety of problems.

An outstanding quality of Doctor Headlee in research was an active but controlled imagination and a spirit of pioneering. Those fortunate enough to be associated with him marvelled at his unending source of ideas and suggestions. However, he was able always to keep his visionary projects firmly anchored to a practical point of view.

Doctor Headlee was a scholar with wide interests. This was recognized by his associates at Rutgers who elected him to Phi Beta Kappa. He was also a member of Sigma Xi and of Alpha Zeta.

Besides being a long time member of the Association and serving as its President, Doctor Headlee was a charter member of the Entomological Society of America; fellow, American Association for the Advancement of Science; life member of the New Jersey State Horticultural Society; member of Eastern and National Plant Boards and member of several mosquito associations and societies.

Doctor Headlee was a man of positive opinions, forthright in speech and manner, impatient with sham and intolerant of injustice. Those closely associated with him will agree that an outstanding characteristic of his was loyalty to his associates, sympathetic interest in their work and in their personal welfare, and a warm and enduring personal friendship. He is survived by his wife, Blanche Ives and three daughters: Mrs. Floyd Markham of New York, Mrs. Carl Stover and Miss Ruth Headlee of Dayton, N. J.

L. M. PEAIRS AND BYRLEY F. DRIGGERS

RECENT PERSONNEL CHANGES IN THE BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE

NEW APPOINTMENTS

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Andrew J. Turner
Room 836-B, 641 Washington St., New York 14, N.Y.

Gordon D. Hall
Box 83 Goldsboro, N.C.

Rose Ella Warner

James E. Vaughan

Hinton H. Ballard
Box 43, Gulfport, Miss.

Lee Hartline

Calvin E. Shepard

Albert D. Griffith

Lamont Mill

Van T. George, Jr.

Jack B. Mercer

Farris Ivie

Andrew J. Coppinger, Jr.

William T. Nailon
Box 4066, Houston, Tex.

Division of Insects Affecting Man and Animals

James P. Toffaletti

Val E. Weyl
Box 5144, Dallas, Tex.

Charles L. Smith
Box 608 Menard, Tex.

Division of Mexican Fruitfly Control

Thomas W. Ammerman
Falfurrias, Tex.

Roy C. Page
Box 31, Mission, Tex.

Virgil A. Thompson
Box 1263, McAllen, Tex.

Division of Grasshopper Control

Arthur Geiser

John H. Ferguson

131 Speer Boulevard
Denver 3, Colorado

Division of Forest Insects

Rabley W. Nash

Valentine M. Carolin, Jr.

Charles M. Speers

Robert I. Roggie

Robert L. Bean
56 Hillhouse Ave., New Haven, Conn.

Division of Foreign Plant Quarantines

Robert A. Zirker
Box 943, Douglas, Ariz.

John A. Lindsay

Paul T. Riherd

Russell A. Nicholson

Lawrence Nagler

William Marr

Walter F. Condon
Box 688, Nogales, Ariz.

Bernard B. Sugerman
Room 800, U.S. Customhouse, 610 S. Canal St., Chicago 7, Ill.

Olen E. Hunt

George H. Berg

Alfred C. Curtiss, Jr.

John L. Ward
Room 907, Pere Marquette Bldg., 150 Baronne St., New Orleans 12, La.

Joseph A. Reeves
Room 530 Federal Bldg., Buffalo 3, N.Y.

Ruffin A. Perkins
Room 411, U.S. P.O., Norfolk, Va.

Mortimer D. Leonard
U.S. Dept. of Agriculture, Room 3112, S. Bldg., Washington, D.C.

Ernest Richmond

Edwin F. Corlis

Edmond B. Dennery
Room 24, Agriculture Bldg., San Francisco 5, Calif.

Samuel Beller
Box 401 San Pedro, Calif.

George E. Fowler

Leonard J. Stewart

John H. Conroy

Quinton L. Chapman
Room 844 Federal Bldg., Christopher St., New York 14, N.Y.

John H. Gayden
Box 1033, Brownsville, Tex.

Virgil A. Becker
Box 438 Eagle Pass, Tex.

Young C. Rowan
c/o U.S. Customs International Bridge, Hidalgo, Tex.

Antoine J. Benton

Ralph C. Johnston

Charles F. Towns
Room 127 U.S. Courthouse, El Paso, Tex.

Roger W. Allen
Room 407 P.O. Bldg., Galveston, Tex.

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Edgar F. Faulkner

William Costello
Thomas V. Henneberry
James H. Pruitt
William C. Whitehead
Elgine E. Sims
Elbert W. Jackson
Box 277 Laredo, Tex.

Division of Cotton Insects

Rudolph G. Strong
Box 906, San Benito, Tex.
James E. Gillespy
Box 1218, Waco, Tex.

Division of Plant Disease Control

Robert H. Kliewer
Room 618, Realty Bldg., Spokane 8, Wash.

Division of Insecticide Investigations

Fred I. Edwards, Jr.
Agr. Res. Center, Beltsville, Md.
Ivan A. Welborn, Jr.
Box 70 Whittier, Calif.

RESIGNATIONS

Division of Foreign Plant Quarantines

John W. Bergquist
Box 688, Nogales, Ariz.
David H. Byers
Stephen R. Morgan
Room 24 Agriculture Bldg., San Francisco 5, Calif.
Karl P. Conradi
Room 209 Customhouse Savannah, Ga.
Orrell F. Kent
Room 710 Pere Marquette Bldg., New Orleans, La.
Edgar F. Faulkner
Henry S. Farmer
Lloyd V. France
Room 844 Federal Bldg., Christopher St., New York 14, N.Y.
Bruce T. Bryant
Room 212 Federal Bldg., Honolulu 9, T.H.

Division of Domestic Plant Quarantines

Ralph W. Bunn
Box 7086, New Orleans, La.
Marvin M. High (Retired)
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William Dickison
B. P. Q. Bldg., Gulfport, Miss.

Division of Cereal and Forage

Marshall J. Magner
Box 32, Urbana, Ill.

Division of Pink Bollworm Control

Harry A. Berrier
Box 849, Las Cruces, N.Mex.
James E. Bruton
Box 798, San Antonio, Tex.

Division of Insects Affecting Man and Animals

Clell B. Wisecup
Howard A. Jones
Fred A. Marton
Joseph P. Linduska
Olin M. Longcoy
Fred M. Snyder
Box 3391, Orlando, Fla.

Insecticides Investigations

Pauline T. Diamond
Stanley A. Cristol
Beltsville, Md.

Division of Grasshopper Control

Kelvin Dorward
131 Speer Blvd., Denver 3, Colo.
Sherwin H. Eckley
Room 306 Rule Bldg., Amarillo, Tex.
Robert W. Every
Box 1697, Billings Mont.
Harry E. Gallaway
421 Railroad St., Elko, Nev.

Division of Control Investigations

Paul A. Wake
Agr. Res. Center, Beltsville, Md.
Howard B. Johnson
Box 375, Gulfport, Miss.

Division of Fruit Insects Investigations

John C. Allee
Ernest N. Green
336 Broadway, Chico, Calif.
Russell W. Nelson
Room 503, Realty Bldg., Spokane 8, Wash.

Division of Forest Insect Investigations

Clarence A. Petty, Beltsville, Md.

Division of Japanese Beetle Control

Paul S. Coffin
144 Moody St., Waltham, Mass.

Division of Insect Pest Survey and Information

William A. D. Millson
U.S.D.A., Washington 25, D.C.

REASSIGNMENTS

Division of Foreign Plant Quarantines

Frederick A. Johnston, Jr.
Milton R. Sartor
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Room 844 Federal Bldg., Christopher St., New York, N.Y.
John R. Garrett
James N. Smith
Room 411 Post Office, Norfolk, Va.
Reginald C. Watson
Otto L. Cook
Room 907 Pere Marquette Bldg., New Orleans 12, La.
Caleb P. Daley
309 U.S. Courthouse, Ft. Worth 2, Tex.
Juan D. Gomez
Calvin L. Ritchie
Oliver O. Stout
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Edmond B. Dennery
Marshall M. Ross
Leo Kartman
Harry E. Bronson
Box 840, Honolulu 9, T.H.
Olen K. Hunt
Room 205, 7300 Wingate St., Houston, Tex.
William T. Owrey
Mansel C. Guerry
Joseph Kline
Frank A. Vitrano
Box 3386, San Juan, Puerto Rico
Paul R. Frink
Henry K. Townes, Jr.
Richard G. Oakley
Room 24 Agr. Bldg., San Francisco, Calif.
Warren F. Pippin
John E. Downs
Box 688, Nogales, Ariz.
William G. Whitehead
Box 277, Laredo, Tex.
Jack M. Darden
John H. Gayden
Brownsville, Tex.
Richard Faxon
Marcus A. McMaster
209 River St., Hoboken, N.J.
Louis J. McConnell
601-A Customhouse, Philadelphia 6, Pa.
Edward D. Algert
Room 229 Federal Bldg., San Ysidro, Calif.
Edward A. Richmond
Westover Army Air Field, Westover, Mass.

Division of Plant Disease Control

Wayne F. Painter
Harold A. Brischle
Homer J. Hartman
John C. Gynn
Fred J. Heinrich
Room 618 Realty Bldg., Spokane 8, Wash.
John K. Kroeber
628 E. Michigan St., Milwaukee 1, Wis.
Conrad P. Wessela
Howard Benton
Roy Blomstrom
1440 Broadway, Oakland, 12, Calif.
Edward L. Joy
Room 206 Federal Bldg., Cambridge 39, Mass.
William V. Zimmer
Room 1, Leggett Bldg., Wytheville, Va.
Glenn R. Allison
Room 207 P.O. Bldg., Lansing, Mich.
Leiton E. Nelson
Room 449 P.O. Bldg., Columbus 16, Ohio

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Harold J. Sigsbee
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William L. Caskey
Charles H. Phillips
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Trevor B. Heald
503 Main St., East Orange, N. J.
Frank G. Winn
Box 5271, Richmond, Va.
Dana W. Millay
Box 1083, Kingston, N.Y.
Leston R. Mate
209 River St., Hoboken, N.J.
Ernest L. Williams
264 W. Tazewell St., Norfolk 10, Va.

Division of Pink Bollworm Control

Homer B. Tittle
Box 2919, Miami 18, Fla.
Guy E. Orr
Box 67, Lamesa, Tex.
James S. Parker
Apartado Postal 822, Delicias Chihuahua, Mex.
Joseph H. Kelley
Box 232, Taft, Tex.
Joseph N. Crisler
Room 11, U.S. Courthouse, El Paso, Tex.
Hugh S. Cavitt
Harlingen, Tex.
Arthur L. Anderson
Big Spring, Tex.
Joseph C. Gay
Box 849, Las Cruces, N.Mex.
William H. Hare
Box 482, Alice, Tex.

Division of Insecticides Investigation

Jack E. Fahey
1237 Washington Ave., Vincennes, Ind.
Fred Acree, Jr.
Milton S. Schechter
Beltsville, Md.

Division of Truck Crop and Garden Insects

Kenneth E. Gibson
Box 1106, Walla Walla, Wash.
Howard E. Dorst
Box 109, Logan, Utah

Division of Control Investigations

E. M. Livingstone
George R. Swank
Box 375, Gulfport, Miss.
Sam C. Munson
Robert H. Nelson
Agr. Res. Center, Beltsville, Md.
Jacob W. Bulger
Room 11 U.S. Courthouse, El Paso, Tex.

Division of Forest Insects

Joseph S. Yuill
Charles B. Eaton
Roger F. Anderson
Joseph M. Davis
Beltsville, Md.
Herbert C. Secrest
Gates Cook Bldg., Gulfport, Miss.
Harold A. Jaynes
56 Hillhouse Ave., New Haven, Conn.
Noel D. Wygant
Colorado State College, Fort Collins, Colo.
Henry Bess
623 N. Second St., Milwaukee, Wis.
Van E. Romney
Whiteford L. Baker
Box 156, Columbus 9, Ohio

Division of Domestic Plant Quarantines

Orville M. White
Box 4066, Houston, Tex.
Kermet H. Applewhite
Gulfport, Miss.
Homer C. Triplett
Box 816, Burgaw, N.C.
Jay B. Smith
Gordon D. Hall
Box 938, Wilmington, N.C.
William G. Johnston
Box 487, Hope Mills, N.C.
Clinton H. Rothe
Box 1066, Riverside, Calif.

Division of Insects Affecting Man and Animals

Raymond C. Bushland
Box 3391, Orlando, Fla.
Hansell F. Cross
Frank S. Faulkner
Harold N. Johnston
Box 208, Dallas 1, Tex.

Division of Fruit Insects

Samson R. Dutky
Box 150, Moorestown, N.J.
George H. Kaloostian
Box 1291, Yakima, Wash.

Division of Cereal and Forage

Elmer W. Beck
2256 Collingwood Ave., Toledo, Ohio
Jesse W. Ingram
Ralph Mathes
Eli K. Bynum
Box 387, Houma, La.

Division of Cotton Insects

Tom P. Cassidy, BEPQ
Washington 25, D.C.

Division of Grasshopper Control

Kelvin Dorward
Marvin C. Kramer
Sherwin H. Eckley
131 Speer Blvd., Denver 3, Colo.
Ivar Twilde
Box 1697, Billings, Mont

Division of Insect Identification

William D. Field
Louise M. Russell
Paul W. Oman
BEPQ—Washington 25, D.C.

Division of Mexican Fruitfly Control

Roy C. Strong, Jr.
Elsa, Tex.

Division of Bee Culture

Will A. Stevenson
Univ. of Arizona, Tucson, Ariz.

PROCEEDINGS OF THE THIRTIETH ANNUAL MEETING

Pacific Slope Branch, American Association of Economic Entomologists

Mission Inn, Riverside, Calif., June 26, 27, and 28, 1946

The 30th Annual Meeting of the Pacific Slope Branch, A.A.E.E., was held at the Mission Inn, Riverside, California, on June 26–28, 1946, jointly with the Entomological Club of Southern California.

The first session was opened with a brief ceremony in commemoration of the founding of the Western Plant Quarantine Board, which was organized at the Mission Inn in Riverside 27 years ago. Chairman Ryan called attention to the names of several people attending the 1919 meeting who were also present in 1946, and then called on Dr. George H. Hecke, director of the California State Dept. of Agriculture in 1919, who was instrumental in calling the meeting which resulted in the organization of the Board. Mr. Ryan also called attention to the fact that the 4th annual meeting of the Pacific Slope Branch was held at Riverside immediately following the Quarantine conference.

At the Wednesday morning session there was a symposium on "Plant Quarantine" with invitational papers by H. M. Armitage, W. L. Popham, Frank McKenna, and C. E. Cooley.

The Thursday morning session was devoted to the subject of "Biological Control" with addresses by C. P. Clausen, Harry S. Smith, W. F. Sellers, Edward A. Steinhaus, S. E. Flanders, and J. K. Holloway.

At the Thursday afternoon and evening sessions the subject under discussion was "New Insecticides" with addresses by C. W. Kearns, F. A. Gunther, Geoffrey Woodward, W. H. Lange, Jr., L. D. Goodhue, Roy Hansberry, and C. E. Palm.

Other sessions were devoted to paper reading on miscellaneous entomological subjects.

After the banquet on Wednesday evening, entertainment consisting of 12 acts of vaudeville was provided through the courtesy of members of the insecticide industry.

On Friday afternoon on the grounds of the University of California Experiment Station at Riverside, there was given a demonstration of modern insecticide application equipment. Among the machines demonstrated were: airplane sprayers and dusters, fumigation tent pullers, fumigation guns, various types of dusters, sprayers, and spray-dusters, thermal fog generators, soil fumigation units, grasshopper bait mixers and spreaders, steam sterilizers, and weed sprayers. In all, 43 units were exhibited and demonstrated.

Attendance at the meetings was large, and sustained interest was shown in all the addresses and papers throughout the meeting. There was a total registered attendance of 345, with the following members present:

Members, American Association of Economic Entomologists Present at Riverside Meeting Pacific Slope Branch, June 26–28, 1946

Armitage, H. M., Sacramento, Calif.
Burtch, L. A., Bakersfield, Calif.
Bartlett, Blair, Riverside, Calif.
Brown, G. T., San Francisco, Calif.
Bottger, G. T., Anaheim, Calif.
Brown, A. O., Oakland, Calif.
Barnes, M. M., Riverside, Calif.
Boyce, A. M., Riverside, Calif.
Broadbent, Miss B., Whittier, Calif.
Barnes, D. F., Fresno, Calif.
Binney, Walter, Chula Vista, Calif.
Bishop, Roy K., Orange, Calif.
Bumgardner, R. J., Orange, Calif.
Cummings, Walter, Santa Barbara, Calif.
Clark, John R., Riverside, Calif.
Crawford, Harvy J., Chico, Calif.
Campbell, Roy E., Alhambra, Calif.
Clausen, C. P., Washington, D. C.
Carman, G. E., Riverside, Calif.
Cooley, C. E., San Francisco, Calif.
Carisoza, James E., South Gate, Calif.
Dorman, S. D., Emeryville, Calif.
Doyle, E. T., San Francisco, Calif.
De Bach, Paul, Riverside, Calif.
Doutt, R. L., Riverside, Calif.
Duggen, Charles E., Pomona, Calif.
Dickson, R. C., Riverside, Calif.
Daniels, Victor E., Los Angeles, Calif.
Durham, Wallace, Los Angeles, Calif.
Ebeling, Walter, Los Angeles, Calif.
Elmore, John C., Alhambra, Calif.
Ewart, W. H., Riverside, Calif.
Essig, E. O., Berkeley, Calif.
Fowler, Jack, Woodland, Calif.
Fenton, Alfred, Houston, Texas
Foyne, C. V., Pasadena, Calif.
Ferris, C. A., San Jose, Calif.
Fu, Sheng-fa, Berkeley, Calif.
Flebut, A. J., Berkeley, Calif.
Flanders, S. E., Riverside, Calif.
Fleshner, C. A., Riverside, Calif.
Freeborn, Stanley B., Berkeley, Calif.
Francis, W. J. F., Tacoma, Wash.
Gressitt, J. L., Berkeley, Calif.
Glover, Leon C., Modesto, Calif.
Gerhardt, Paul D., Riverside, Calif.
Gammon, Cyril, Ontario, Calif.
Goodhue, Lyle D., Neodesha, Kan.
Hansberry, Roy, Modesto, Calif.
Holloway, James K., Albany, Calif.
Hills, Orin A., Phoenix, Ariz.
Hanna, Lester W., Hillsboro, Ore.
Howland, A. F., Alhambra, Calif.
Hoskins, W. M., Berkeley, Calif.
Heming, W. E., Whittier, Calif.
Irvine, Milton, Riverside, Calif.
Jeppson, Lee, Riverside, Calif.
Jones, Laurence S., Riverside, Calif.
Johnson, Esler, San Francisco, Calif.
Jonson, W. L., Pasadena, Calif.
Jones, M. P., Washington, D. C.
Jewel, Edward S., Pomona, Calif.
Kearns, Clyde W., Urbana, Ill.
Korsmeier, R. B., Seal Beach, Calif.
Kirkpatrick, A. F., Monrovia, Calif.
Kagy, J. F., Seal Beach, Calif.
Konkright, B. J., Salinas, Calif.
Loeffler, E. S., Berkeley, Calif.

Lange, W. H., Jr., Davis, Calif.
Lyle, Clay, State College, Miss.
La Follette, J. R., Whittier, Calif.
Lewis, H. C., Whittier, Calif.
Landon, Wm. E., San Dimas, Calif.
La Due, J. P., Riverside, Calif.
Lindgren, D. L., Riverside, Calif.
Lichty, Ralph W., Los Angeles, Calif.
Marsh, Harry L., Los Angeles, Calif.
Mather, Stanley M., Los Angeles, Calif.
McCorkindale, L. D., Lancaster, Calif.
Miller, Ralph, Ontario, Calif.
Michelbacher, A. E., Berkeley, Calif.
Miller, J. M., Hollywood, Calif.
Middlekauff, Woodrow, Berkeley, Calif.
Martin, Chas. H., Corvallis, Ore.
Mote, Don C., Corvallis, Ore.
Melander, A. L., Riverside, Calif.
Miller, Marvin P., Glendora, Calif.
MacLeod, G. F., Fresno, Calif.
Nelson, Howard D., Whittier, Calif.
Newton, J. H., Paonia, Colo.
Oretega, Jack, Riverside, Calif.
O'Neill, W. J., Wenatchee, Wash.
Palmer, Dean, San Diego, Calif.
Parker, Wm. B., Placerville, Calif.
Popham, W. L., Washington, D. C.
Persing, C. O., San Francisco, Calif.
Platt, Fred R., Riverside, Calif.
Palm, C. E., Ithaca, N. Y.
Papke, Cliff, Whittier, Calif.
Quayle, H. J., Riverside, Calif.
Richards, Claude A., Los Angeles, Calif.
Roark, Len, Visalia, Calif.
Roney, J. N., Phoenix, Ariz.
Riehl, L. A., Riverside, Calif.
Ryan, Harold J., Los Angeles, Calif.
Sanders, Earl, Santa Ana, Calif.
Simmons, Perez, Fresno, Calif.
Smith, Gordon, Berkeley, Calif.
Smith, Leslie M., Davis, Calif.
Scott, David B., Jr., Altadena, Calif.
Sheldon, Howard B., Santa Paula, Calif.
Stafford, E. M., Davis, Calif.
Smith, Harry S., Riverside, Calif.
Smith, Sam S., Sacramento, Calif.
Steinhaus, Ed. A., Berkeley, Calif.
Stewart, M. A., Berkeley, Calif.
Strand, T. P., Richmond, Calif.
Smith, L. G., San Francisco, Calif.
Stanger, Neal, Ukiah, Calif.
Swain, A. F., Los Angeles, Calif.
Stone, M. W., Ventura, Calif.
Timberlake, P. H., Riverside, Calif.
Vogel, M. A., Yakima, Wash.
Vertrees, J. D., Portland, Ore.
Webster, R. L., Pullman, Wash.
Wilcox, Joseph, Alhambra, Calif.
Wampler, E. T., Anaheim, Calif.
Woodhams, Geo. D., San Bernardino, Calif.
Wilcomb, Howard, Los Angeles, Calif.
Worthy, Walter L., Camarillo, Calif.
Woglum, R. S., Los Angeles, Calif.
Yust, Harold R. Whittier, Calif.
Zapf, R. A., Santa Monica, Calif.

Auditing, Nominating, and Resolutions Committees were appointed at the opening session, and reported at the final session. All committee reports were accepted by unanimous vote.

TREASURER'S REPORT

(For a 2-year period) 1944–1946

June 27, 1944, Balance in bank		$28.08
August 1, 1944, Refund for 1944 expenses		59.10
December 7, 1945, Interest on bank account		.61
Total		$87.79
1945 Expenses		
Mimeographing & mailing notices	$23.42	
Envelopes & postage	2.61	
Telegrams & telephone	4.57	
1946 Expenses		
Letterheads & stamps	5.61	
Mimeographing & mailing announcements and notices	88.82	
Printing programs & tickets	27.32	
Lettering signs for meeting place	7.08	
Rental of loud speaker for meeting	26.50	
Telegrams	2.62	
Rental of loud speaker for demonstration	15.00	
Total	$203.55	
Deficit		*−115.76*

APPROVED: Auditing Committee
WALTER EBELING, CHARLES MARTIN, C. O. PERSING, *Chairman*

NOMINATING COMMITTEE REPORT

Officers for 1946–1947:

Chairman—M. A. Stewart, Davis, California

Vice-Chairman—Wm. J. O'Neill, Wenatchee, Washington

Secretary-Treasurer—Roy E. Campbell, Alhambra, California

Nominating Committee:
DON MOTE
A. J. FLEBUT,
E. O. ESSIG, *Chairman*

The report of the Resolutions Committee was as follows:

RESOLUTIONS OF THE PACIFIC SLOPE BRANCH, AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

WHEREAS, The Thirtieth Annual meeting of the Pacific Slope Branch of the American Association of Economic Entomologists, held at the Mission Inn, in Riverside, California, June 26–28, 1946, has been a profitable and memorable gathering, and,

WHEREAS, The outstanding success of these meetings has been due to the generous efforts and contributions of many individuals and groups, therefore be it

Resolved, That the thanks of the Pacific Slope Branch be recorded as follows:

1. To Clay Lyle, President of the American Association of Economic Entomologists, and to Dr. George Hecke for being with us.

2. To those, who, upon invitation made valuable contributions to the program.
3. To the special committees whose work did so much to organize the meetings and to keep them functioning effectively.
4. To the staff of the Citrus Experiment Station for their efforts in our behalf.
5. To the member firms of the insecticide industry for furnishing an enjoyable evening.
6. To the Entomological Club of Southern California for joining in the meetings.
7. To the Chamber of Commerce of the City of Riverside for furnishing secretarial service and covers for our programs.
8. To the management and employees of the Mission Inn for their helpful services.
9. To George M. Brown, nurseryman of Riverside, for furnishing floral decorations for the tables at the Entomologists' Dinner.
10. To the Agricultural Extension Service for the use of projection lanterns and screens.

WHEREAS, Increasing traffic between countries has greatly augmented the danger of the introduction of foreign insects, therefore be it

Resolved, That the Pacific Slope Branch lend its strong support to undertakings which will increase our knowledge of foreign insect pests, to modernizing and strengthening our plant quarantine defenses, and to extending domestic surveys to detect promptly the establishment of new insect enemies.

WHEREAS, The science of entomology has been so greatly expanded and

WHEREAS, So many data of intestimable value are being developed and should be reported, and

WHEREAS, The time available at the anuual meetings of the Pacific Slope Branch of the American Association of Economic Entomologists is so limited and inadequate, therefore be it

Resolved, That the members of this association request their officers to consider the policy at future meetings of the following:

1. Condensation of the oral presentation of the papers.
2. Making available, at the time of the meetings, mimeographed copies of the complete reports.

Resolved, That the Pacific Slope Branch, American Association of Economic Entomologists, go on record as being in favor of Senate Bill 1850 for the creation of a National Science Foundation:

That entomological work be included in the Biology, Medical, and National Defense Sections, as provided in Bill 1850:

That Entomologists be included in the Administrative Committee which may operate these Sections:

That the entomological phases of work in these Sections be organized and administered by qualified entomologists and associated professions.

Signed DEAN F. PALMER
Signed PEREZ SIMMONS
Chairman

E. F. KNIPLING SUCCEEDS E. C. CUSHING IN BUREAU

The appointment of Edward F. Knipling to head the Division of Insects Affecting Man and Animals of the Bureau of Entomology and Plant Quarantine was announced on September 15 by P. N. Annand, Chief of the Bureau. Emory C. Cushing, former head of the Division, resigned to return to his ranch near San Antonio, Texas.

Mr. Knipling was born at Port Lavaca, Texas, March 20, 1909. He holds the degrees of Bachelor of Science from Texas A. & M., and Master of Science from Iowa State College. Since joining the Bureau in 1931, his work has been almost entirely in the field of medical and veterinary entomology. He was senior entomologist in charge of the Orlando Laboratory during the war years. The entomologists and chemists of the Bureau, at this laboratory, developed or adapted practically all insecticides, repellents, and methods employed for their application, used by the armed forces during World War II. The United States Typhus Commission Medal was awarded Mr. Knipling on May 13, 1946 for his share in these developments.

Mr. Cushing has been connected with the Division of Insects Affecting Man and Animals since 1928 except for his period of service as Colonel in the Sanitary Corps with the armed forces from 1942 to 1946. He was awarded the Typhus Medal in May, 1945. He was first appointed head of the Division in 1941 and returned to that position this past February. The early wartime research programs conducted by the Bureau in the field of medical entomology were initiated by Mr. Cushing before he entered military service.